

20 MACGYVER TIPS **AUTO AWARDS**
THE TRUTH ABOUT GREEN JOBS

Popular Mechanics

Science Automotive Technology Home Outdoors

POPULARMECHANICS.COM | DECEMBER 2009



Mustang Shelby GT500

2010

ANATOMY OF A PLANE CRASH

WHAT HAPPENED
TO AIR FRANCE
FLIGHT 447?

HOW DISASTER
FORENSICS
MAKES FLYING
SAFER

NEW TOOLS
TO BANISH
PILOT
ERROR

BUILDING
SAFER
AIRPORTS,
PLANES,
COCKPITS

PLUS

GEAR OF THE YEAR:
25 GREAT
GADGETS

DRILL DRIVER
SHOWDOWN



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× DECEMBER

Test Drives



NEW CARS

When a car, truck or motorcycle is production-ready, PM's auto editors are there first. Our editors and professional drivers take you behind the wheel, testing handling, acceleration and the high-tech innovations in new vehicles long before you can buy them. Whether we're roaring through laps on the race track, canyon-carving or hypermiling on the highway, we'll tell you everything the automakers did right—and what they got wrong. popularmechanics.com/automotive

ELECTRIC HYBRIDS

If there's an electric vehicle on the road—whether two-, three- or four-wheeled—chances are we've driven it. The prototype plug-in Toyota Prius, the Ford Fusion Hybrid, the 100-mpg electric Hummer and plenty more high-tech vehicles have faced our road tests. Check back for more on how the latest electric and hybrid electric vehicles hold up in real-world driving. popularmechanics.com/phev

LONG-TERM RELIABILITY

Sometimes even a 300-mile drive isn't enough to reveal every detail on a new car or truck. That's why PM's auto editors have a fleet of vehicles that we submit to year-long reliability tests. Check in for weekly comments and full quarterly updates. popularmechanics.com/longtermtestcars

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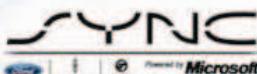
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WHAT THEY'RE DOING



DAVID E. COLE

Chairman, Center for Automotive Research
Cole is working to encourage the adoption of renewable portfolio standards, which commit states to supply customers with increased electrical power from renewable sources in coming years. The automotive-trend expert also helped organize The Business of Plugging In, a conference exploring the political and economic issues involved in promoting plug-in electric vehicles on a large scale.



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PM LETTERS

Beyond Survival

The October "Self-Reliance Issue" was simply excellent. The stories and messages are a wake-up call for all of us to improve our skills and become more self-sufficient—whether in building a shelter, growing food, surviving natural disasters or simply doing projects around the home. I also thought your emphasis on coordinating efforts noteworthy. Teamwork is of paramount importance if we are to triumph over the challenges of our modern world.

BOB KARD
SAN DIEGO, CA

Your story "The Electric Cold-Beer Gadget Test" proves just how materialistic we are as a society—in a crisis situation, most thoughts would be toward finding a way to maintain creature comforts and not on ways to survive. "But, Dad, I'm bored!" Oh? Well, kick up that generator and waste a limited resource like gas. This article should not have been in this issue. Survival is not about comforts, it's about maintaining life.

SCOTT RANDALL
IRON RIVER, MI



10/09

Readers responded to self-reliance themes—from fixing old machines to surviving natural disasters.

I am a long-time subscriber to POPULAR MECHANICS, but I have never before read your magazine from cover to cover with as much interest as I did the October issue, "Beyond Survival." I reside in California and have an earthquake shed filled with supplies, including a tent, water, sleeping bags and a portable radio. Your survival issue will be added to my kit. Thank you from a dedicated PM reader.

JIM FREEMAN
RICHMOND, CA

Extraordinary Skills

I recently read "The Rules of Survival" and was inspired by all the stories of ordinary people surviving incredible disasters. One, however, hit particularly close to home: I spent many weekends at the Little Sioux Scout Ranch in Iowa, where a troop survived a tornado in 2008. As an adolescent, I practiced many of the skills that those scouts

had to call upon after the disaster. The boys are a testament to a program that has withstood the test of time in preparing ordinary boys to be extraordinary men under the most extreme circumstances.

CHRIS KOSLOSKY
TOPEKA, KS

Forget the Landfill

I very much enjoyed your story "The Soul of an Old Machine" about the movement to repair and fix rather than discard products. I too enjoy the challenge of fixing something, even if just for the satisfaction of accomplishing the task. Recently I helped a neighbor diagnose a problem with his 30-year-old wood splitter. The cost of replacing the worn piston seals was just \$4 plus some replacement hydraulic fluid. Bottom line: We saved \$1500 and a lot of space in the landfill.

BILL LAMMERS
OCALA, FL



In bookstores this month:

Extreme Fear: The Science of Your Mind in Danger, by PM contributing editor Jeff Wise. Based on reporting that originally appeared in PM, real-life stories of death and survival enliven this exploration of the brain's fear response.

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do you
think?

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Or something better?

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72 Anatomy of a Plane Crash

A jet flying from Rio de Janeiro to Paris vanishes without a trace. How can investigators prevent a similar tragedy if the cause remains unknown? PM looks for answers.

BY JEFF WISE

80 So You Want to Buy a Netbook

This 2-pound wonder combines a desktop computer's functionality with a laptop's take-along convenience—at a fraction of the price. We dissect features to help you find the right mini machine.

BY SETH PORGES

82 Run Silent, Run Sleek

With its unprecedented speed and maneuverability, the Super Falcon submarine promises to reveal underwater worlds to scientists and amateur explorers alike.

BY MARK SCHROPE

88 The Guerrilla Mechanic

Our in-house MacGyver, auto editor Mike Allen, shares his 20 favorite quick-fix secrets, from making a fuel injector out of a Bic pen to a jury-rigged fencepost remover.

BY MIKE ALLEN

90 The New Wildcatters

As America's petroleum heartland, Texas isn't known for being environmentally sensitive. But its oil-boom, get'er-done attitude could make clean energy take off.

BY JENNIFER BOGO

98 Are Green Jobs for Real?

Green jobs have become known as the fix-it-now Band-Aid for some big economic quandaries. But will Earth-friendly careers stick around long enough to make a lasting impact?

BY JOE P. HASLER

Dan Templeton, director of the Wind Energy Technology program at Texas State Technical College, in the nacelle of a 2-megawatt DeWind turbine.

ON THE COVER

Photo illustration of an Airbus 330 commercial passenger airline. Original photograph by Doug Ball.



NEW TOOLS
CARS
HOME
HOW-TO

2010 **AUTOMOTIVE
EXCELLENCE
AWARDS**

PM's crack automotive department tests and evaluates more than 100 new cars and trucks every model year. Here's the best of the best—or at least the ones they couldn't break.

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TECH WATCH

13 Superman's Velcro

The toughest hook-and-loop material on earth. **Plus:** NASA figures out how to levitate mice; can Bill Gates conquer hurricanes?

UPGRADE

31 2010 Wish List

Two dozen must-have toys, tools and tech items. **Plus:** Wireless sound systems endure our Abusive Lab Test; sci-fi-worthy tech that you can buy today.

COLUMNS

**70 The New
Machine Age**

Some experts say computers will soon surpass the intelligence of the human brain. Glenn Harlan Reynolds explores the implications.

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Popular Mechanics

PM DEPARTMENTS

pm do-it-yourself

HOME

**105 Bantamweight
Slugfest**

PM puts some serious pressure on seven 12-volt lithium-ion drills in a test to crown the best portable powerhouse.



AUTO

**115 Saturday
Mechanic**

Own a classic car? Keep its engine purring even longer by mastering a pair of age-old arts: replacing the ignition points and setting the timing.

TECH

**125 Digital
Sketchbook**

Put that pencil down—drawing on a PC is as easy as sketching on paper. With the right equipment and a little artistic skill, you can make a digital masterpiece.

**110 Homeowners
Clinic**

Using the right hardware to maximize the hang time of heavy wall art. **Plus:** The proper way to install a snow fence; LEED-certified green remodeling.

118 Car Clinic

Buyer beware—cheap, low-quality offshore brake discs. **Plus:** Ford's Sync system deciphers Check Engine lights; dealing with a gasoline/diesel mix-up at the pump.



Ever since your washer's been gone,
your dryer feels empty inside.

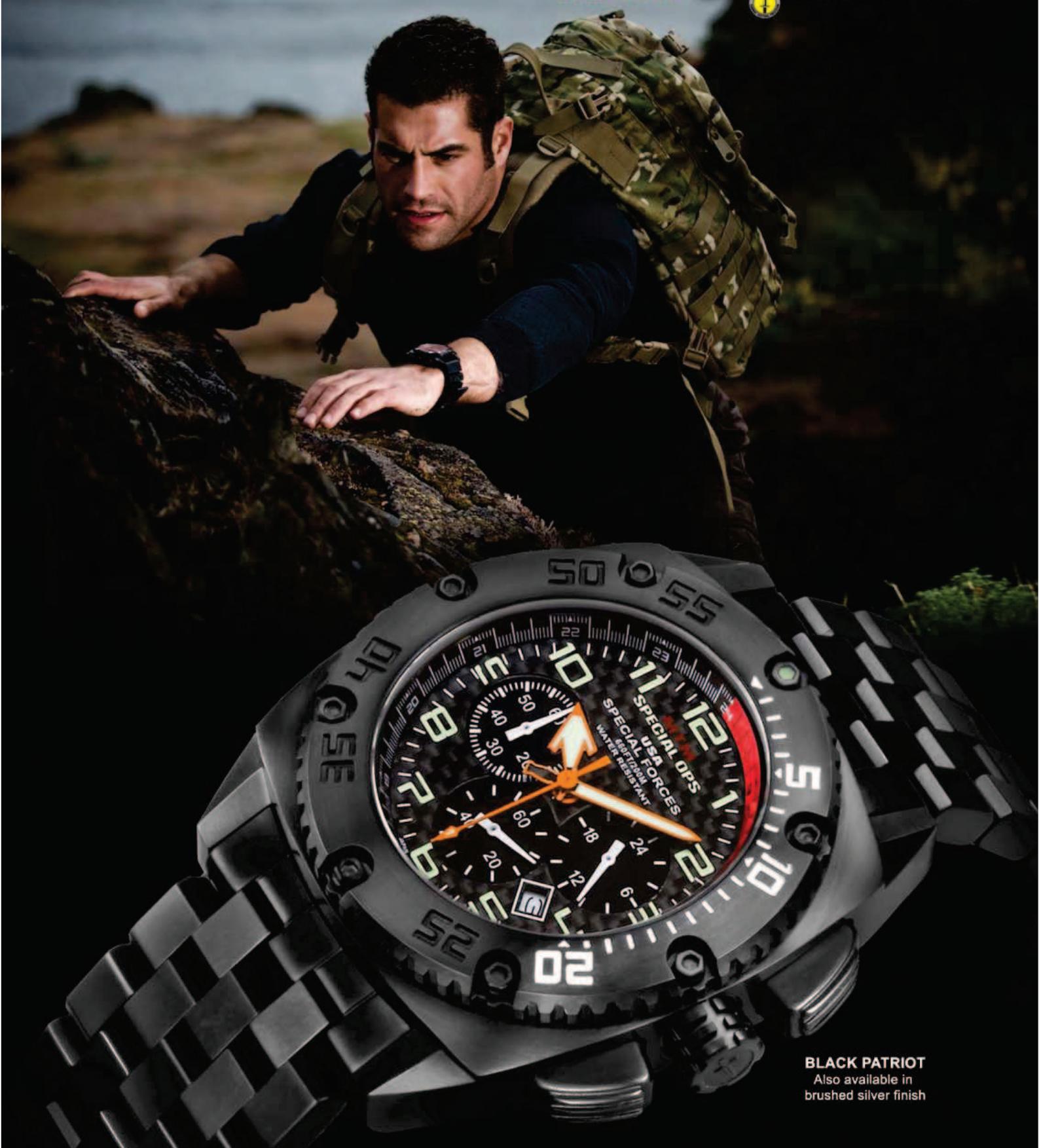


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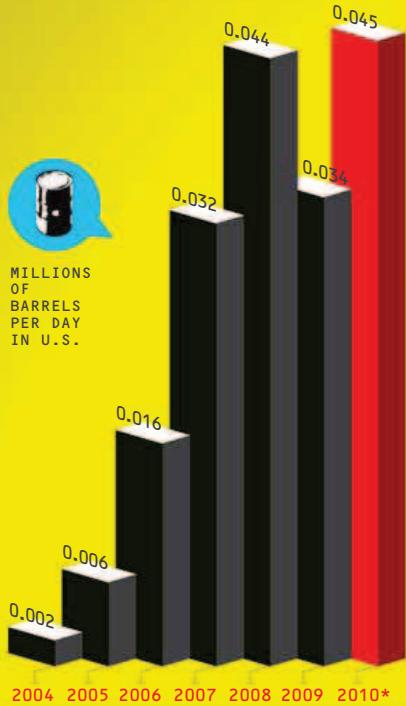
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*2010 number projected by
U.S. Department of Energy

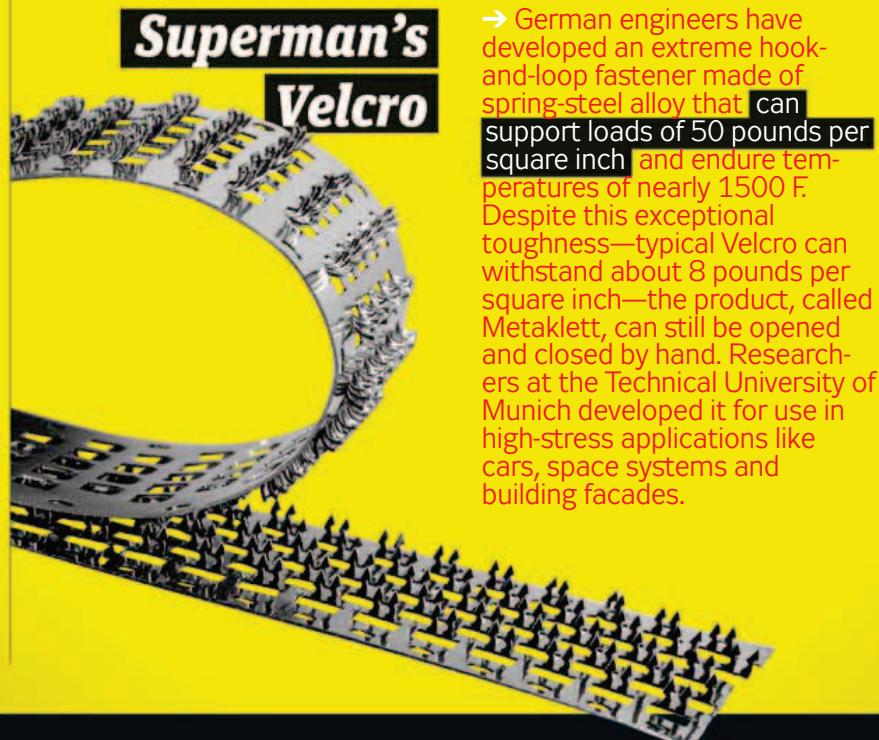
HOT TIMES IN THE CITY
+ It's well-known that cities are an average of 6 degrees Fahrenheit warmer than the surrounding countryside—and the difference can be as high as 22 F. But a team of European scientists wanted to know how street width, green spaces and air pollution affect temperature. The scientists gathered radiation and temperature data from sensors on the ground, in airplanes and on NASA satellites to measure differences between Athens and its suburbs. The team is now examining the data for trends; European emergency planners will use the findings to better position ambulances during deadly heat waves.

STEAMY SUBMARINE CHAT LINE
+ Researchers at the Naval Research Laboratory have figured out how to focus laser beams to produce a

controlled burst of underwater sound. Using a mix of lasers that emit slightly varying frequencies of light, the process superheats a small area of water,

producing a small explosion of steam and a 220-decibel sound pulse. A sequence of these flashes turns the water itself into a speaker. Within the next

year, the Navy will attempt longer-distance experiments that could enable one-way communication from aircraft to submerged submarines.



→ German engineers have developed an extreme hook-and-loop fastener made of spring-steel alloy that can support loads of 50 pounds per square inch and endure temperatures of nearly 1500 F. Despite this exceptional toughness—typical Velcro can withstand about 8 pounds per square inch—the product, called Metaklett, can still be opened and closed by hand. Researchers at the Technical University of Munich developed it for use in high-stress applications like cars, space systems and building facades.



More than
100
unique
mutations
exist within
each
person's
DNA

A JOINT TEAM FROM ENGLAND AND CHINA SEQUENCED THE Y CHROMOSOME OF TWO MEN WHO WERE SEPARATED BY 13 GENERATIONS AND COUNTED THE GENETIC DIFFERENCES. MOST OF THESE MUTATIONS HAVE NO INFLUENCE ON APPEARANCE OR HEALTH, BUT SOME CAN CAUSE DISEASES.

Charge 'Er Up

THE WORLD'S MOST AMBITIOUS ELECTRIC CAR COMPANY WILL RELY ON ROBOTIC STATION ATTENDANTS TO CHANGE BATTERIES.

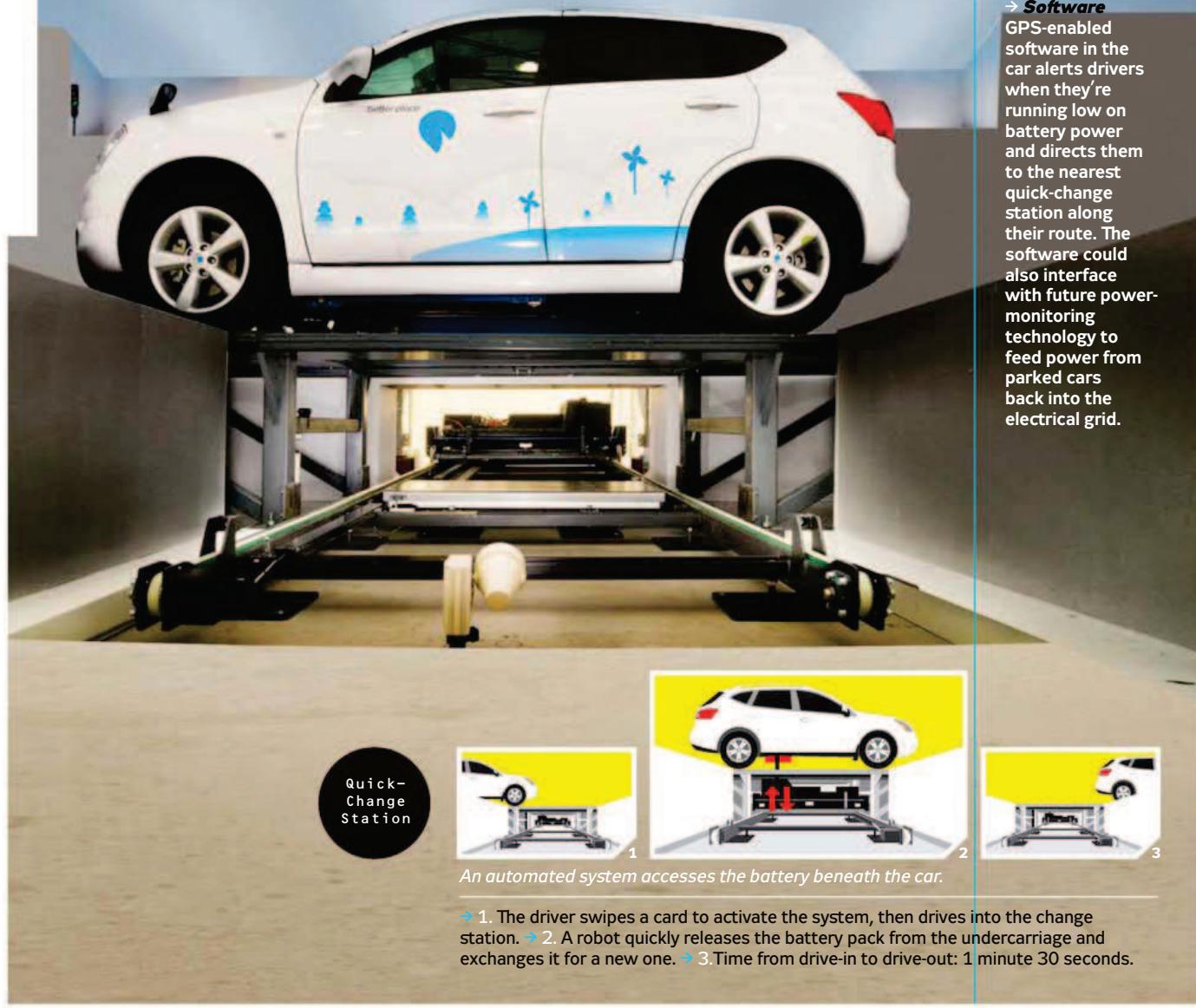
BY MICHAEL BELFIORE

→ **It takes more** than just a vehicle to convince consumers to adopt electric cars. Recharging their batteries has to be as easy as filling up a tank of gas. Israel-born entrepreneur Shai Agassi, the founder of the startup company Better Place, is relying on robotic quick-change stations to swap out depleted batteries for fresh ones in the electric cars he is servicing. Drivers will enter a station when their battery pack gets low and have the battery replaced faster than it would take to refill a gasoline tank. "When electric cars are more affordable and convenient than gas cars, consumer adoption will tip the market," Agassi says. Better Place proposes building a network of curbside charging stations where owners can top off their vehicle batteries. Agassi's idea generated \$300 million in venture capital and sparked international interest: Cities in Israel and Denmark hope to have the first robotic change stations running in 2011, and the company aspires to expand operations to Australia, Canada, Hawaii and California in 2012. In late September, Better Place signed a deal with Renault-Nissan to put 100,000 electric vehicles on the road in Israel and Denmark by 2016.

→ **Battery**
The several-hundred-pound pack, powered by lithium-ion cells like those in laptop computers, mounts flush with the bottom of the car. Better Place will own the batteries along with the infrastructure for servicing them.

→ **Plug**
Like electric cars currently on the market, the Better Place model has an electric plug so that drivers can top off at curbside charging stations.

→ **Software**
GPS-enabled software in the car alerts drivers when they're running low on battery power and directs them to the nearest quick-change station along their route. The software could also interface with future power-monitoring technology to feed power from parked cars back into the electrical grid.



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THE AIR FORCE'S NUCLEAR RESET

→ Sometimes a single bad day can reshape an entire military service. The U.S. Air Force was humiliated in late 2007 when aircrews unwittingly loaded six live

nuclear warheads onto a B-52 bomber, believing them to be unarmed cruise missiles. The nukes were missing for 36 hours, flying from Minot Air Force Base in North Dakota to Barksdale Air Force Base in Louisiana,

before anyone noticed. The top brass relieved four officers of their commands and decertified 65 airmen from handling nuclear weapons, but **the Air Force's post-Cold War neglect of its nuclear missions had been exposed.**

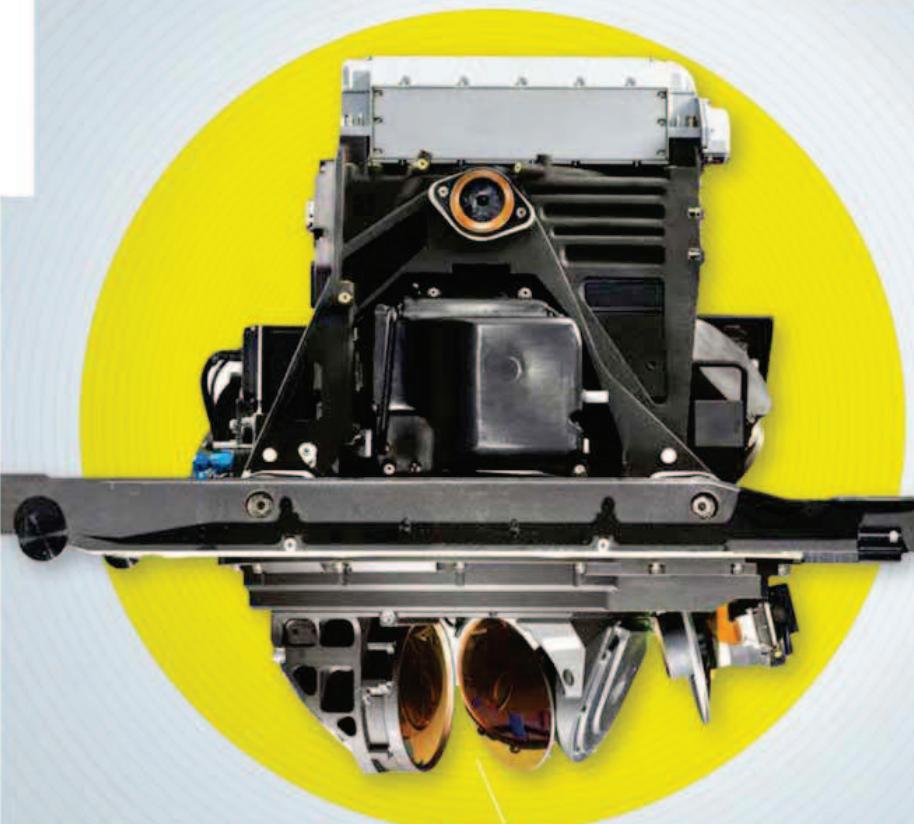
In response, the Pentagon decided in October 2008 to consolidate responsibility for its fleet of nuclear-capable bombers and land-based intercontinental ballistic missile missions under the watchful eye of a

single command. The Global Strike Command takes charge of the ICBMs this month in Barksdale, but most of the nuclear-capable B-2 and B-52 bombers will transfer to the new command in February. —J.P.



The F-35's Deadeye

AEROSPACE DESIGNERS GIVE THE JOINT STRIKE FIGHTER A SAPPHIRE-PANELED GEM OF AN AIMING SYSTEM. BY JOE PAPPALARDO



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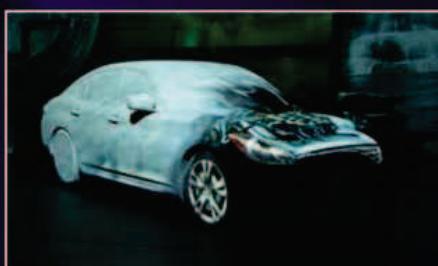


TO FIND ONESELF INSPIRED.

Infiniti believes it's a journey that must be felt, not told. So they started by imagining "inspiration" as a physical concept, conceiving a tented interior onto whose 4 walls they projected a 15-foot-tall cinematic experience.

Using state-of-the-art projections, Infiniti created a 2-hour pictorial sojourn with an ever-morphing Infiniti M at its center.

Elements in the virtual car's "inspired journey" to a final vehicle included: (1) the life-size CAD model, (2) the 3D technician maneuvering projections to fit the model, (3) and (4) "revelation" of the state-of-the-art motor via projection, (5) a floral nod to nature's inspiration, (6) the complete CAD drawing.



Here, the car is fully "realized" after a journey of projections that seemed to take it from the design table to the road.

Synched with a Bose® surround soundscape, the resulting immersive experience reminded viewers that a drive's *true* destination can simply be the emotions stirred when reaching the people and places one loves. This is the Infiniti journey.

A series of projections over the 2-hour journey captured 4 cinematic themes: (1) the relationship between man and landscape, (2) the symphonic exploration of the creative process, (3) the mastering of machines to bring inspiration to life, (4) the reminder that the soul of a driving experience is found in the journey and not just the destination.

Seen behind the "virtual" Infiniti M is a compilation of projected images captured at the event.



ALL-NEW INFINITI M

Informed by the dynamic harmony of nature and the beauty of balanced movement, the Infiniti M proves that inspiration can give machines a soul. Industry-first technology includes a Blind Spot Intervention System that warns of vehicles next to you and assists in returning your vehicle to its original lane, while its more than 400 horsepower engine and luxurious handcrafted interior exemplify power and a passion for inspired detail.

The all-new Infiniti M will be on sale at your Infiniti retailer in early Spring 2010.





EXPERIENCE INSPIRED EMOTION BROUGHT TO LIFE

A multimedia experience that truly brought the 59th annual Pebble Beach Concours d'Elegance into the 21st century, **The Infiniti Journey of Inspiration** used patented video-mapping technology to project onto, under and behind a full-size "CAD model" of the all-new Infiniti M, seen here. Guests at the event did not view the real car—but were part of an immersive, 360° event designed to capture the Infiniti driving experience—one in which craftsmanship delivers not only motion, but emotion.

Pictured here is one of the computer-generated CAD drawings of the Infiniti M used to "build" the car at the event. Open here to see how drawing and CAD model came together before guests' eyes.

INFINITI.
Inspired Performance

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INFINITI ESSENCE

In addition to the "virtual" Infiniti M, guests at the event were also witness to the North American debut of the stunning Essence Concept Vehicle.

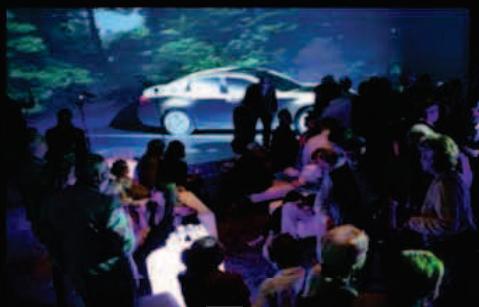
Inspired by the simplicity and flow of a single brushstroke, the Infiniti Essence sport coupe is positioned at the true cutting edge of automotive design. Inside, its driver-focused interior blends "new luxury" with traditional Japanese craftsmanship. Equally sophisticated and unobtrusive is its innovative parallel hybrid system, combining a high-output 3.7-liter twin-turbo V6 engine with a new ultra-slim "3D" electric motor. Achieving the perfect balance between grace and power, Essence is the embodiment of Infiniti. Once seen, never forgotten.



This experience was developed by The Apartment, a design agency focused on creating fully integrated, transformative ideas; and Klip Collective, producers of innovative, site-specific video installations.

Since 1950, the Pebble Beach Concours d'Elegance has been the world's premier celebration of the automobile. To see how Infiniti's state-of-the art journey brought inspiration to life at this legendary event, visit

www.Infiniti.com/journeyofinspiration



The unprecedented union of power and efficiency.

Like most things, power is relative. To understand the significance, you need a point of reference. Something to compare it to. When you compare the VVEL engine of the 2009 Infiniti G Sedan to its predecessor, you notice two things. One is that it generates significantly more power. The other, which completely defies conventional thought, is that it uses less fuel to generate this power: It's able to do this by continually adjusting valve timing and lift for quicker response and a broader torque curve. Maximizing every ounce of power the gasoline has to offer. Delivering a more noticeable connection between you, the engine and the road. A level of artistry that can't be seen. But can most certainly be felt.

The 328-hp, 3.7-liter Infiniti G Sedan.



*Compared against prior generation non-VVEL engines. 2009 EPA fuel economy estimates: 18 city/26 hwy. Actual mileage may vary. Always wear your seat belt, and please don't drink and drive. ©2009 INFINITI.



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Death Match

RESEARCHERS WILL USE ANY STRATEGY, EVEN TRAINING INSECTS, TO LOCATE AND IDENTIFY CADAVERS. *BY AMBER ANGELLE*

→ **Forensic scientists** work with law enforcement to locate and identify corpses at crime scenes and in the wake of disasters. Forensic teams typically rely on highly trained cadaver dogs that are expensive to maintain. DNA or dental records are then used to determine a recovered body's identity. Although these well-honed methods are considered the gold standard, forensic experts are faced with scenarios where these conventional tools are impractical, as when the body is badly decomposed or buried by debris. These new tools are being developed.

BUG BLOODHOUNDS

→ Forensic scientists use insects to estimate the time of death of recovered corpses, but researchers have begun to realize they can also be trained to find bodies. Insects can be cheap and flexible alternatives to cadaver dogs. Researchers at the University of Georgia have trained wasps to differentiate minute quantities of putrescine and cadaverine, chemicals released by decaying bodies.

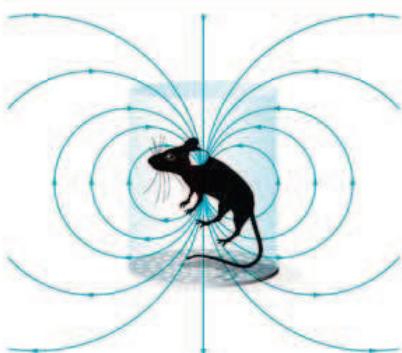
DIGITAL SNIFFER

→ Researchers are also seeking to replicate the skills of cadaver dogs by creating a portable electronic device that is programmed with the chemical profile of odors released by decaying bodies. A team at Penn

State is creating a profile of the different odors produced as a corpse decays by monitoring euthanized pigs kept under varying environmental conditions. They are recording the types and amounts of chemicals released over the course of three weeks. They plan to correlate the chemical profiles with changes in the phases of insect activity in corpses to improve accuracy in determining time of death.

NUMBERED BODY PARTS

→ Decomposition can cause forensic experts to seek alternatives to DNA. When other methods fail, investigators can match the serial numbers on silicone breast implants, dental prostheses and titanium hips with records from the manufacturer. Some dental pieces are even inscribed with the owner's name.



NASA's Levitating Mice → Researchers at NASA's Jet Propulsion Laboratory seeking ways to study the effects of weightlessness on astronauts have succeeded in levitating small mice using a 17-tesla magnet. The magnetic field is so strong that it affects the water in the animal's tissues, prompting a repulsive magnetic force that suspends the rodent in the air. It takes a superconducting magnet operating at minus 456 F to float a 10-gram mouse within a 2.6-inch bore, which is kept at room temperature. The magnetic field is applied evenly to keep the mice hovering in place, and scientists say rodents acclimate to the test in about 4 hours. Lessons learned could prevent astronaut bone deterioration during long missions.

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Bill Gates, Hurricane Hunter

GEEKY IDEAS BECOME HOT COMMODITIES AT A RESEARCH SHOP OPERATED BY SOME OF THE WORLD'S WEALTHIEST INVESTORS. BY BRIAN THEVENOT

Bill Gates has dominated the software industry, become one of the wealthiest men in the world and remade his image as a master philanthropist. But can he stop a hurricane?

Gates, the chairman of Microsoft, is steering company funds to Intellectual Ventures, a private company that buys and licenses patents and inventions. Gates himself participates in the firm's brainstorm sessions. Next on the list: killing hurricanes. Warm surface water fuels big storms, so Intellectual Ventures proposes to suppress them by dumping cool water from massive floating bowls of unspecified size, deployed by

airplane in front of a storm's path. It would take a water surface temperature drop of 4.5 F to diminish a hurricane's force, says Kerry Emanuel, professor of atmospheric science at MIT, and hundreds of bowls would have to be deployed over hundreds of miles. "I actually don't think it's feasible," says George Mellor, a Princeton professor who envisioned a similar system years ago. "But it's worth researching, and, hey, if Bill Gates is investing ..."

INTELLECTUAL VENTURES **Employees:** 500-plus **Funding:** \$5 billion in venture capital from investors (including Microsoft) **Revenues:** Company officials told a newspaper earlier this year it has made more than \$1 billion in licensing fees since inception.

COLD-WATER OUTFLOW
UP CONDUIT FOR COLD WATER
DOWN CONDUIT FOR WARM WATER
TURBINE

OTHER IDEAS FROM GATES'S IDEA FACTORY

Mosquito Laser Defense

→ Researchers at a recently opened Intellectual Ventures lab in Bellevue, Wash., are building the ultimate bug zapper. The "photonic fence" combats malaria by surrounding houses or villages with a perimeter guarded by lasers that shoot mosquitoes from the air. The

computer-guided laser can track the flight of individual mosquitoes, and distinguish harmless males from biting females by measuring the frequency of their wing beat. Crucially, the laser beam is weak enough that humans can pass through the perimeter unharmed. The system has been successfully tested in the firm's labs.

Super-Strength Semiconductors

→ Intellectual Ventures recently

purchased the entire patent portfolio of Transmeta, a trailblazing manufacturer of low-power microprocessors. Transmeta was purchased in 2009, but the company that bought it was only interested in microprocessors for video displays, and sold 140 other patents to Intellectual Ventures. The technologies could lead to powerful, efficient computer chips to use in expendable remote sensors, medical devices inside human bodies and nano-scale manufacturing.

HOW IT WORKS: THE VESSEL FILLS WITH WATER AS WAVES SLAP OVER THE SIDES. THE PRESSURE OF THE WATER'S WEIGHT FORCES WATER DOWN A TUBE, WHERE THE DOWNWARD CURRENT TURNS A TURBINE. THAT TURBINE SUCKS COOL WATER FROM THE DEPTHS INTO THE TUB.

ILLUSTRATION BY TRANSLUSZENT

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A FILM'S VISUAL EFFECTS SEQUENCES CAN BE CRAFTED BY MORE THAN 100 ARTISTS AND CAN TAKE MONTHS TO CREATE. HERE ARE A FEW OF THE KEY STEPS IN THE PROCESS.

1. Live-Action Plate

→ Emmerich filmed actors and a limo with a Panavision Genesis camera in front of a 750-foot-long, 42-foot-tall blue screen.

2. Matchmove

→ CG artists identify points in the plate that can be tracked over all frames of a shot. Using that information, software calculates the exact movement of the original live-action camera and re-creates that movement inside the computer.



3. Scene Assembly

→ When the elements of a scene are finished, the set is assembled in the computer; VFX artists do a test render to make sure all the elements work correctly.



4. Final Shot

→ Frame by frame, assets undergo render passes for light, shadows and more. The virtual assets and live elements are composited on the plate, giving the appearance of a single shot that has been photographed live.



Apocalypse How

DIRECTOR ROLAND EMMERICH GIVES INSIDE TIPS ON HOW TO DESTROY THE WORLD—ON FILM. *BY ERIN MCCARTHY*

→ Roland Emmerich is no stranger to cinematic disaster. The director froze New York City in *The Day After Tomorrow* and blew the White House to bits in *Independence Day*. So he wasn't sure about directing *2012*, out Nov. 13. The movie is based on the idea that the end of the Mayan calendar on Dec. 21, 2012, portends a global apocalypse. "When I realized how much disaster was involved I got a case of cold feet, because I've done that, you know?" he says. "So I said, 'Okay, I'm going to make this the mother of all disaster movies.'"

More than 100 artists created *2012*'s 1300 visual effects (VFX) shots, including volcanic eruptions, tsunamis, floods—and a massive earthquake that rips California apart. In this 3-minute sequence, failed science-fiction writer Jackson Curtis (John Cusack) drives through Los Angeles as the city crumbles around him. In the past, Emmerich might have filmed on location and swapped in CG crumbling buildings, but that approach didn't make sense for *2012* because every edifice had to be destroyed. Instead, artists at Uncharted Territory built a 3D photorealistic version of several city blocks using 60,000 high-dynamic images as a reference. Then they made every mailbox, tree and building shake and crumble—and each item had to be researched to see how it would behave.

As animators molded the virtual city, Emmerich was filming his actors in front of a blue screen. He put the actors on a "shaky floor," an 8000-square-foot steel platform on airbags. Special-effects coordinators jiggled the bags with pneumatic pumps to inspire authentic reactions from the actors. "It was the most complicated scene we created," Emmerich says. "And it's one of my favorites."

ON THE WEB >

The shots above represent only a few steps of the visual effects process. For a gallery of *2012*'s VFX work from start to finish, plus an interview with director Roland Emmerich on the science behind the movie, visit popularmechanics.com/2012movie.

Talk to your doctor.

Adding ABILIFY to an antidepressant such as one of these* can help treat unresolved symptoms of depression.



Approximately 2 out of 3 people being treated for depression still have unresolved symptoms.

Ask your doctor about the option of adding ABILIFY to your current antidepressant.

ABILIFY is FDA-approved to treat depression in adults when added to an antidepressant.

*Or generic equivalents where available.

IMPORTANT SAFETY INFORMATION:

Elderly patients with dementia-related psychosis (eg, an inability to perform daily activities due to increased memory loss) taking ABILIFY have an increased risk of death or stroke. ABILIFY is not approved for treating these patients.

Antidepressants can increase suicidal thoughts and behaviors in children, teens, and young adults. Serious mental illnesses are themselves associated with an increase in the risk of suicide. When taking ABILIFY call your doctor right away if you have new or worsening depression symptoms, unusual changes in behavior, or thoughts of suicide. Patients and their caregivers should be especially observant within the first few months of treatment or after a change in dose. Approved only for adults 18 and over with depression.

- Alert your doctor if you develop very high fever, rigid muscles, shaking, confusion, sweating, or increased heart rate and blood pressure, as these may be signs of a rare but potentially fatal condition called neuroleptic malignant syndrome (NMS)
- If you develop abnormal or uncontrollable facial movements, notify your doctor, as these may be signs of tardive dyskinesia (TD), which could become permanent
- If you have diabetes or have risk factors or symptoms of diabetes, your blood sugar should be monitored. High blood sugar has been reported with ABILIFY and medicines like it. In some cases, extreme high blood sugar can lead to coma or death
- Other risks may include lightheadedness upon standing, decreases in white blood cells (which can be serious), seizures, trouble swallowing, or impairment in judgment or motor skills. Until you know how ABILIFY affects you, you should not drive or operate machinery

The common side effects in adults in clinical trials ($\geq 10\%$) include nausea, vomiting, constipation, headache, dizziness, an inner sense of restlessness or need to move (akathisia), anxiety, and insomnia. Tell your doctor about all the medicines you're taking, since there are some risks for drug interactions. You should avoid alcohol while taking ABILIFY.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

Please read the Important Information about ABILIFY on the adjacent page.

*Lexapro® (escitalopram oxalate), Zoloft® (sertraline HCl), Prozac® (fluoxetine hydrochloride), Effexor XR® (venlafaxine HCl), Paxil CR® (paroxetine HCl) are trademarks of their respective companies.



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IMPORTANT INFORMATION ABOUT ABILIFY

This summary of the Package Insert contains risk and safety information for patients about ABILIFY. This summary does not include all information about ABILIFY and is not meant to take the place of discussions with your healthcare professional about your treatment. Please read this important information carefully before you start taking ABILIFY and discuss any questions about ABILIFY with your healthcare professional.

Name

ABILIFY® (a-BIL-i-Fe) (ariPIPrazole) (air-ri-PIP-rah-zole)

What is ABILIFY?

ABILIFY (ariPIPrazole) is a prescription medicine used as an add-on treatment to antidepressants for Major Depressive Disorder in adults.

What is depression?

Depression is a common but serious medical condition. Symptoms may include sadness, loss of interest in activities you once enjoyed, loss of energy, difficulty concentrating or making decisions, feelings of worthlessness or excessive guilt, insomnia or excessive sleep, a change in appetite causing weight loss or gain, or thoughts of death or suicide. These could be depression symptoms if they interfere with daily life at home, at work, or with friends and last most of the day, nearly every day for at least 2 weeks.

What is the most important information that I should know about antidepressant medicines, depression, and other serious mental illnesses?

- Antidepressant medicines may increase suicidal thoughts or actions in some children, teenagers, and young adults
- Depression and serious mental illnesses are the most important causes of suicidal thoughts and actions

For more information, see the Prescribing Information and the Medication Guide called *Antidepressant Medicines, Depression and Other Serious Mental Illnesses, and Suicidal Thoughts or Actions*.

Who should NOT take ABILIFY?

People who are allergic to ABILIFY or to any substance that is in it. Allergic reactions have ranged from rash, hives and itching to difficulty breathing and swelling of the face, lips, or tongue. Please talk with your healthcare professional.

What is the most important information that I should know about ABILIFY?

Elderly patients, diagnosed with psychosis as a result of dementia (for example, an inability to perform daily activities as a result of increased memory loss), and who are treated with antipsychotic medicines including ABILIFY, are at an increased risk of death when compared to patients who are treated with a placebo (sugar pill). ABILIFY is not approved for the treatment of patients with dementia-related psychosis.

Antidepressants may increase suicidal thoughts or behaviors in some children, teenagers, and young adults, especially within the first few months of treatment or when the dose is changed. Depression and other serious mental illnesses are themselves associated with an increase in the risk of suicide. Patients on antidepressants and their families or caregivers should watch for new or worsening depression symptoms, unusual changes in behavior, or thoughts of suicide. Such symptoms should be reported to the patient's healthcare professional right away, especially if they are severe or occur suddenly. ABILIFY is not approved for use in pediatric patients with depression.

Serious side effects can occur with any antipsychotic medicine, including ABILIFY. Tell your healthcare professional right away if you have any conditions or side effects, including the following:

Stroke or ministroke in elderly patients with dementia: An increased risk of stroke and ministroke has been reported in clinical studies of elderly

patients with dementia (for example, increased memory loss and inability to perform daily activities). ABILIFY (ariPIPrazole) is not approved for treating patients with dementia.

Neuroleptic malignant syndrome (NMS): Very high fever, rigid muscles, shaking, confusion, sweating, or increased heart rate and blood pressure may be signs of NMS, a rare but serious side effect that could be fatal.

Tardive dyskinesia (TD): Abnormal or uncontrollable movements of face, tongue, or other parts of body may be signs of a serious condition known as TD, which may be permanent.

High blood sugar and diabetes: Patients with diabetes and those having risk factors for diabetes (for example, obesity, family history of diabetes), as well as those with symptoms such as unexpected increases in thirst, urination, or hunger should have their blood sugar levels checked before and during treatment. Increases in blood sugar levels (hyperglycemia), in some cases serious and associated with coma or death, have been reported in patients taking ABILIFY, and medicines like it.

Orthostatic hypotension: Lightheadedness or faintness caused by a sudden change in heart rate and blood pressure when rising too quickly from a sitting or lying position (orthostatic hypotension) has been reported with ABILIFY.

Leukopenia, Neutropenia, and Agranulocytosis: Decreases in white blood cells (infection fighting cells) have been reported in some patients taking antipsychotic agents, including ABILIFY. Patients with a history of a significant decrease in white blood cell (WBC) count or who have experienced a low WBC due to drug therapy should have their blood tested and monitored during the first few months of therapy.

Suicidal thoughts: If you have suicidal thoughts, you should tell your healthcare professional right away.

Dysphagia: Medicines like ABILIFY have been associated with swallowing problems (dysphagia). If you had or have swallowing problems, you should tell your healthcare professional.

What should I talk to my healthcare provider about?

Patients and their families or caregivers should watch for new or worsening depression symptoms, unusual changes in behavior and thoughts of suicide, as well as for anxiety, agitation, panic attacks, difficulty sleeping, irritability, hostility, aggressiveness, impulsivity, restlessness, or extreme hyperactivity. Call your healthcare provider right away if you have thoughts of suicide or if any of these symptoms are severe or occur suddenly. Be especially observant within the first few months of antidepressant treatment or whenever there is a change in dose.

Tell your healthcare provider about any medical conditions you may have and all medicines that you are taking or plan to take, including prescription and over-the-counter medicines, vitamins, or herbal products.

Be sure to tell your healthcare provider:

- If you have suicidal thoughts
- If you have or have had a low white blood cell count (WBC)
- If you or anyone in your family have or had seizures
- If you or anyone in your family have or had high blood sugar or diabetes
- If you are pregnant, plan to become pregnant, or are breast-feeding

What should I avoid when taking ABILIFY?

- Avoid overheating and dehydration
- Avoid driving or operating hazardous machinery until you know how ABILIFY affects you
- Avoid drinking alcohol
- Avoid breast-feeding an infant

What are the possible side effects of ABILIFY (ariPIPrazole)?

Common side effects in adults include: nausea, vomiting, constipation, headache, dizziness, an inner sense of restlessness or need to move (akathisia), anxiety and insomnia. It is important to contact your healthcare professional if you experience prolonged, abnormal muscle spasm or contraction which may be signs of a condition called dystonia.

This is not a complete list of side effects. For full patient information, visit www.abilify.com. Talk to your healthcare professional if you have questions or develop any side effects.

What percentage of people stopped taking ABILIFY due to side effects?

In clinical trials, the percentage of adults who discontinued taking ABILIFY due to side effects was 6% and 2% for patients treated with sugar pill.

Can I safely take ABILIFY while I'm taking other medications?

ABILIFY can be taken with most drugs; however, taking ABILIFY with some medicines may require your healthcare professional to adjust the dosage of ABILIFY.

Some medicines* include:

- ketoconazole (NIZORAL®)
- quinidine (QUINIDEX®)
- fluoxetine (PROZAC®)
- paroxetine (PAXIL®)
- carbamazepine (TEGRETOL®)

It is important to tell your healthcare professional about all the medicines you're taking, just to be sure.

How should I take ABILIFY?

- Take ABILIFY exactly as directed by your healthcare professional
- ABILIFY is usually taken once a day and can be taken with or without food
- If you miss a dose, take it as soon as you remember. However, if it is time for your next dose, skip the missed dose and take only your regularly scheduled dose
- Talk to your healthcare professional before stopping ABILIFY or changing your dose

General advice about ABILIFY:

- ABILIFY should be kept out of the reach of children and pets
- Store ABILIFY Tablets and the Oral Solution at room temperature
- For patients who must limit their sugar intake, be aware that ABILIFY Oral Solution contains sugar
- For patients who cannot metabolize phenylalanine (those with phenylketonuria or PKU), ABILIFY DISCMELT® contains phenylalanine
- If you have additional questions, talk to your healthcare professional

Find out more about ABILIFY:

Additional information can be found at www.abilify.com

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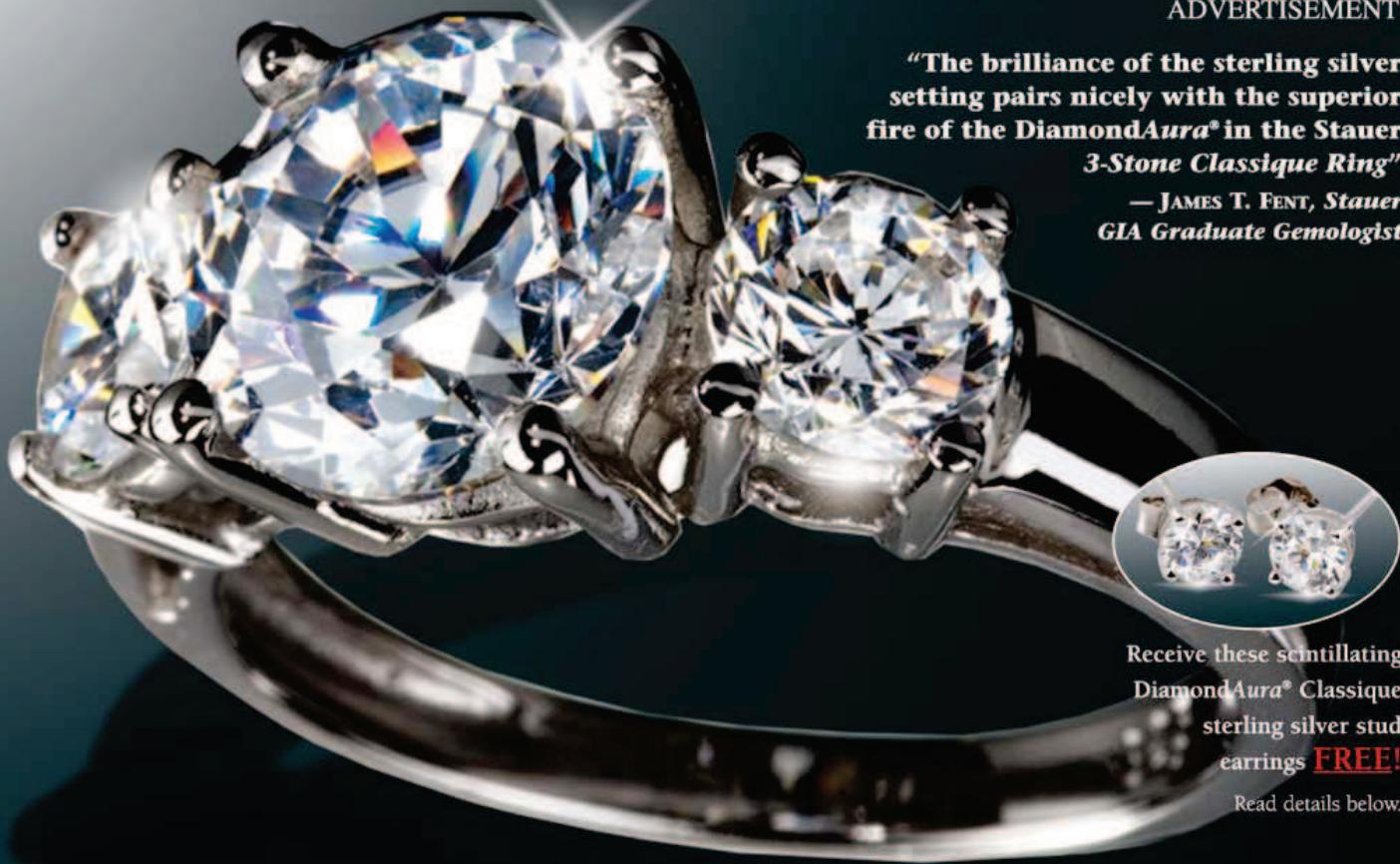
U.S. Patent Nos. 5,006,528; 6,977,257, and 7,115,587.

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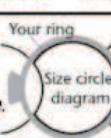
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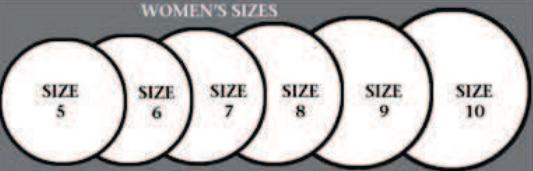
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→ This year's guide to the best holiday gifts has a little for you, and a little for everyone else. For you: the best new tools and gear, a look at sci-fi tech that you can buy today and an unforgiving lab test of wireless sound systems. For them: family-friendly toys and games that you can enjoy, too. (All right, so it's kind of all for you. We won't tell.)

BY SETH PORGES

WISH LIST



Powermat Home & Office Charging Mat \$100

→ Cellphones, iPods, cameras ... the charging cords for all that gadgetry add up. Powermat's charging mat uses magnetic induction to wirelessly power up to three devices

that have been placed on the pad. The result: The number of wires is knocked down to one (the power has to come from somewhere). But the best is yet to come. The

company claims it's going to build the tech directly into tables—we recently saw a demo of a futuristic kitchen where appliances draw power from the counter.

Powermat's adapters (\$30 to \$40 apiece) allow it to charge phones, cameras, MP3 players, portable game systems, headsets and GPS devices.

SCI-FI TECH YOU CAN BUY TODAY: 32 / THE BEATLES ROCK BAND: 34 / THE TOUGHEST BAND SAW, A SPORTS-FRIENDLY HIGH-SPEED CAMERA, AND SONY'S NEW SLIM PS3: 36 / RED TOOLBOX WOODWORKING KITS: 38 / ABUSIVE LAB TEST—WIRELESS SOUND SYSTEMS: 40 / YOOSTAR GREEN-SCREEN SYSTEM: 42 / A HANDHELD ESPRESSO MACHINE, COMPACT CAMPING COOKSET AND CLASSIC TOBOGGAN: 44

2010

popular
mechanics

WISH LIST

WIRELESS HIGH-DEFINITION

→ Transmitting low-bandwidth music around the house is easy. But the massive amount of data needed to send high-definition digital video through the air makes it a challenge. New technology now makes it possible to cut the HDMI cord and beam hi-def video directly to your TV from a cable box or Blu-ray player. The end game: a completely cable-free house. Wireless high-definition technology is being built directly into some new TVs, and it can be found today in the **Dell Latitude Z Laptop** (starts at \$2000), which uses an add-on receiver to give monitors the ability to pick up the PC's high-definition transmission.

DELL

On the
Cusp

Our guide to sci-fi-worthy next-gen technology that you can pick up today.

3D shutter glasses rapidly black out alternating lenses, allowing each eye to see a different image.

3D AT HOME

→ The 3D home theater is catching up to the multiplex. Shutter glasses such as the **Nvidia 3D Vision Kit** (\$200) work by blacking out one eye at a time, 60 times per second—so fast you don't notice it. An infrared emitter syncs these flashes with a quickly

switching screen, allowing each eye to effectively see a different image. The 3D effect comes from showing the same scene to each eye from a different perspective. Lots of current games can be played in 3D, and software from companies like DDD can convert any off-the-shelf DVD into 3D live, as it plays. Just make sure you have a 3D-compatible display.

MICRO- PROJECTORS

→ In the past two years, projectors have shrunk to palm-size portables. They're called "pico" projectors, and Texas Instruments, Microvision and 3M each have takes on the tech, which can be found in gadgets such as the iPod-attachable **WowWee Cinemini Swivel** (\$350). For now, these battery-powered projectors may be

most useful for party tricks, but the tech's tipping point will likely come from its convergence with existing devices. Nikon already has a camera out with a built-in projector, and cellphones aren't far behind.

2/8



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no TO
PEOPLE
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Rock Band**
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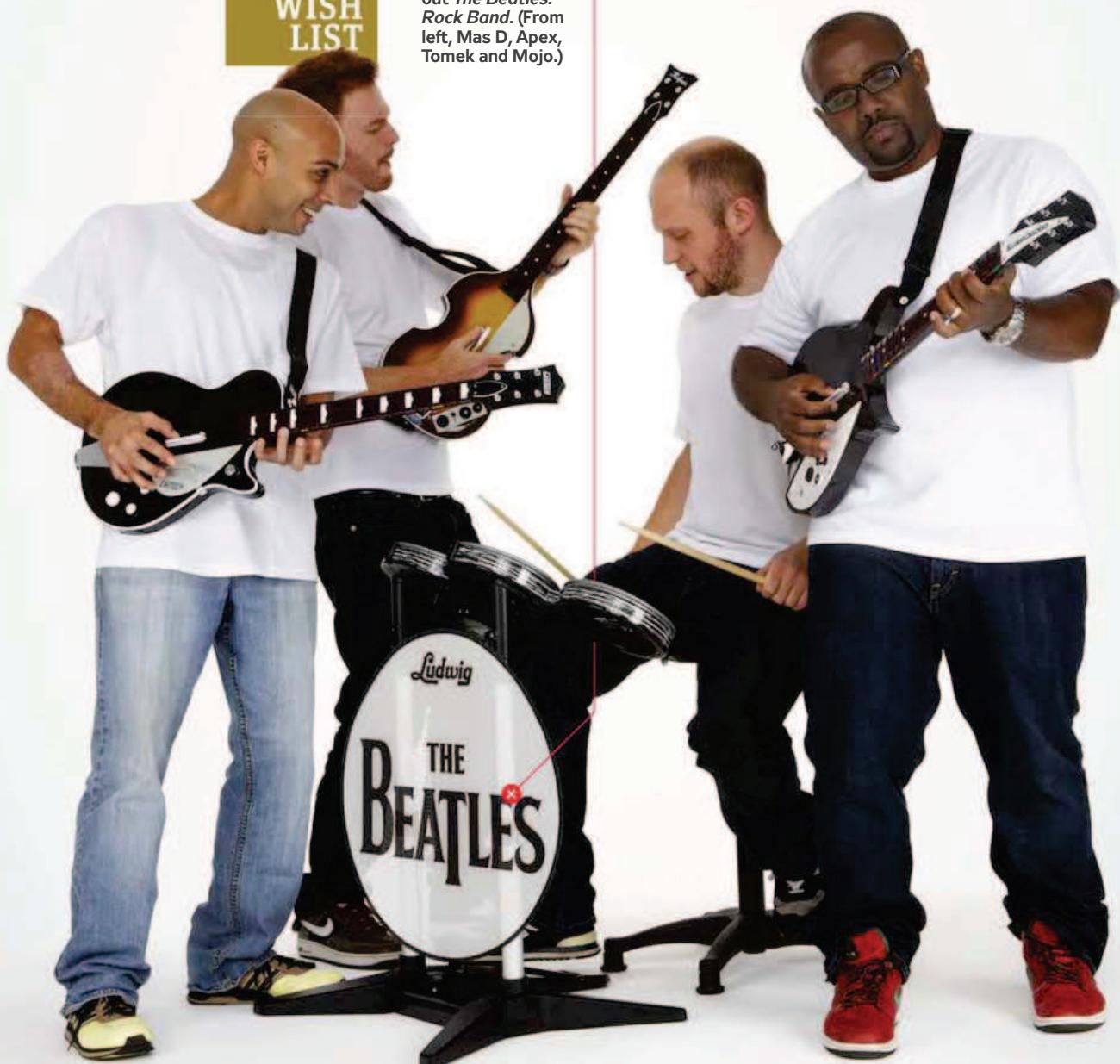
WISH
LIST



→ New York-based band Dujeous come together to test out *The Beatles: Rock Band*. (From left, Mas D, Apex, Tomek and Mojo.)

→ The much-hyped new *Rock Band* release eschews a scattershot set list for a fine focus on the Fab Four. The result: a cross-generational romp through music history that's sure to get some unlikely family members to pick up plastic instruments and drum, strum and sing along with the most beloved band of all time. Call it catnip for Beatlemaniacs, and perhaps the only game this year that works equally well as a gift for dad or the kids.

"The replicas of the instruments are spot-on. It was awesome rocking on Paul's Hofner bass."
—Alex "Apex" Gale, Dujeous bass player and PM copy editor



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IN?



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01

Dyson DC31 Vacuum (\$220)

Dyson's new hand vac features two power modes: scaled back for longer battery life, or turbocharged for tough jobs.

02

Milwaukee M18 Cordless Band Saw (\$400)

Hard falls on concrete are one of the most common causes of death for band saws. Milwaukee's new 18-volt lithium-ion-powered cordless cutting tool is designed specifically to survive such spills.

03

Sony PlayStation 3 120 GB System (\$300)

Sony's PS3 just took a cut in price and size—it's now a third slimmer, uses a third less power and is \$100 cheaper than earlier versions.

04

Casio Exilim EX-FS10 (\$350)

A 30-frames-per-second burst mode makes this the fastest compact camera ever, and the best pick for goal kicks, gymnastics flips and other high-speed action.

05

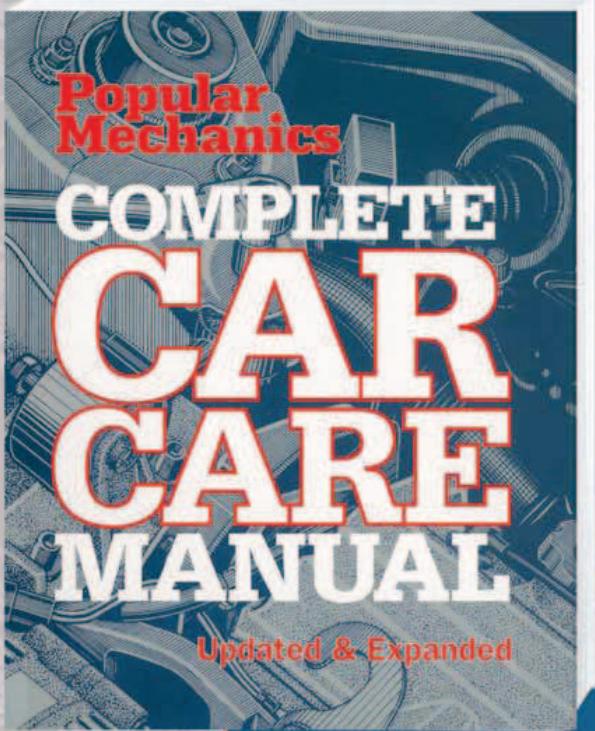
Redington CPX Series 6-Weight Flyrod (\$300) and Redington RISE Reel (\$160)

The 9-foot rod balances power and finesse with a spirally wrapped graphite layup, while the fully machined aluminum reel features a midsize arbor that gobbles in line with each handle crank.

06

Microsoft Zune HD (\$219 for 16 GB, \$289 for 32 GB)

The 3.3-inch OLED display on Microsoft's attempted iPod Touch-killer is one of the best-looking mobile screens we've ever seen. And when paired with an optional dock, the player can pump HD video directly to your TV.



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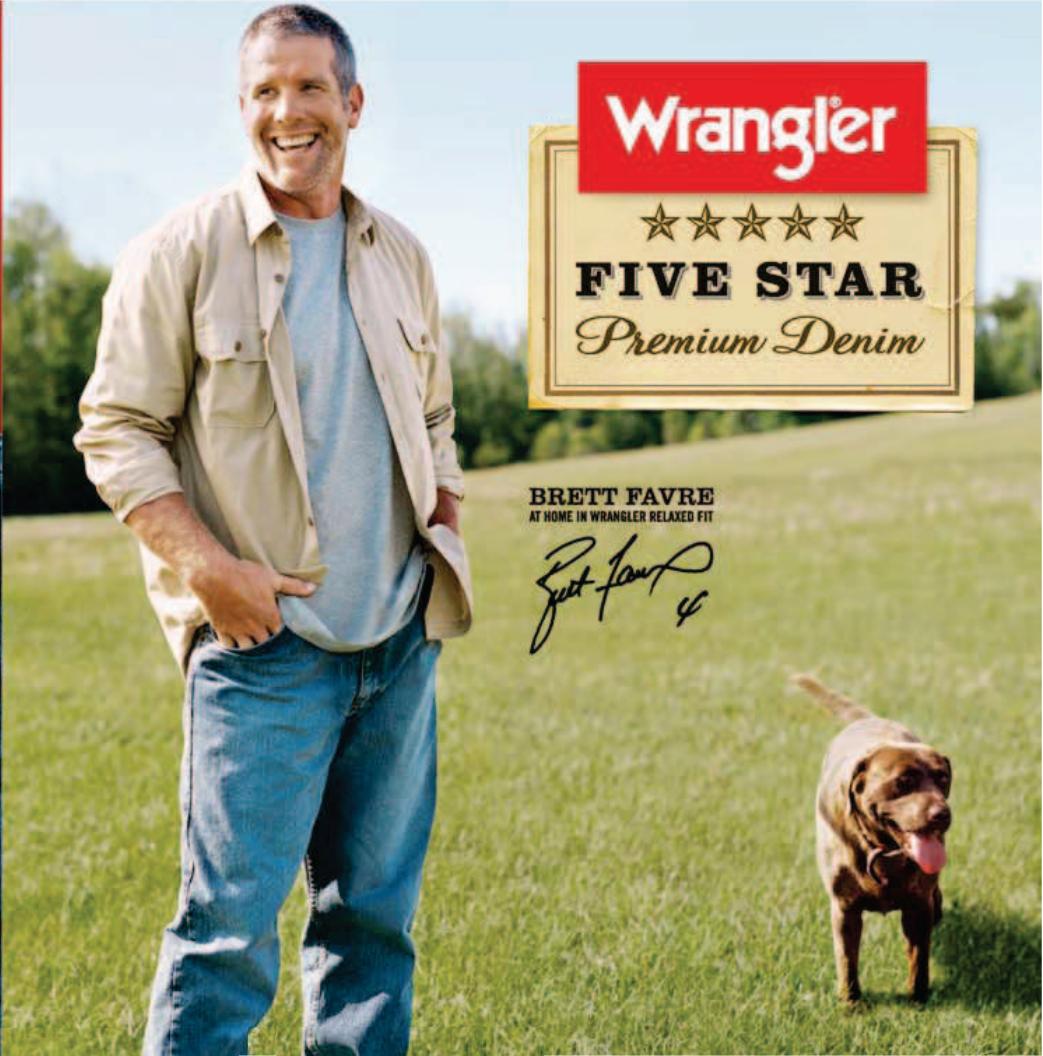
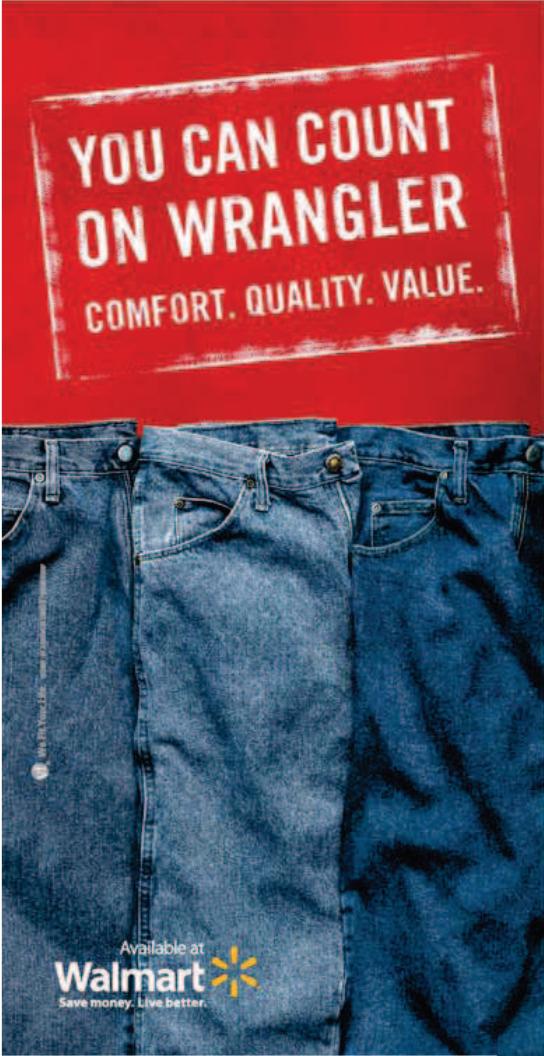
Replace the U-joints.

Maintain your windshield wipers.

Handle steering wheel wander.

Fix faulty cruise control.

Change your oil and filter.



Red Toolbox
Birdhouse
\$27
Classic
Toolbox
\$28

2010

WISH
LIST

popular
mechanics

As more schools cut shop class, it's increasingly up to parents to teach hands-on skills. Red Toolbox's beginning woodworking project kits come with easy-to-follow directions and precut pieces of wood. Intermediate and advanced projects hone a young carpenter's measuring, cutting and drilling skills. Even if the instructions are a bit too brief at times, that's just an opportunity to step in and show a kid how it's done.

"It was fun using a drill for the first time to build the birdhouse."

—Anwen Herbert-Lewis, daughter of PM senior art director Peter Herbert

This toolbox and birdhouse are two beginner-level project kits from Red Toolbox. More advanced projects include soapbox-derby-style go-karts, a model catapult and art deco-style shelving. (Anwen Herbert-Lewis, left, PM contributing editor Davin Coburn and Lilah Herbert-Lewis.)



More Red Toolbox projects



PHOTOGRAPHS BY J MUCKLE/STUDIO D; ILLUSTRATIONS BY GABRIEL SILVEIRA



This season's shows still look great
on last season's HD TV.

Come to think of it, **eBay**

WISH
LIST

→ The average home is filled with wireless signals, all bouncing around in the same limited spectrum space. This can foil a wireless sound system trying to transmit tunes around the house, but some setups handle interference better than others. We tested three systems, including two designed for multiroom use, against a grueling wireless traffic jam. Here's how they fared.

BY SETH PORGES

WIRELESS
INTERFERENCE

We placed the transmitters and receivers in separate rooms, with a phalanx of interference-causing devices between them (see diagram below).

BOSE: The only system to fail this test completely—interference ruined the signal.

SONOS: At first, the signal was completely blocked. But we switched channels and got clear, rich sound.

SOUNDCAST: What interference?

WINNER:

Soundcast

IN-HOME
DISTANCE

How far can the wireless signal travel through a fixture-filled home? We walked the receivers down a concrete-filled apartment building to see.

BOSE: The speaker got almost three stories from the transmitter before breaking into static.

SONOS: Once again, the sound called it quits just shy of three floors down.

SOUNDCAST: Yep, three stories was the limit.

WINNER:

Three-way tie

↓ the tests

EASE OF USE

How stressful was setup?

BOSE: Truly plug-and-play. Pop the USB transmitter dongle into a PC and the streaming begins.

SONOS: Setup took a lot of time and fiddling. But once ready, the system is a snap to control via an iPhone app or remote control.

SOUNDCAST:

Almost as easy to use as the Bose, and effortlessly expandable.

WINNER: Bose

↓ bottom line

The Bose is a practical (if pricey) one-speaker solution. But if your house is full of interference—or you want a multiroom rig—opt for the Sonos or SoundCast. The Sonos is more feature-filled, the SoundCast simpler.



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→ The Yoostar package comes with a green screen, a camera and software for inserting yourself in movies. Twelve short clips are included. Others can be purchased for \$1 to \$4—a price that could quickly add up for repeat customers.



→ Hollywood wizards use green screens to transport actors to distant planets. Now, you can use the same tech to enter classic films. Sit in front of Yoostar's green screen and read your lines off a computer monitor. The program uses a camera (included) to digitally insert you in place of Brando or Hanks, allowing you to go *mano a mano* with some of film's most memorable characters. Completed clips can then be shared on Yoostar's site. Think of it as *Guitar Hero* for the movies.

"I especially liked being put into the toga party in Animal House. It's classic! It made me feel like one of the Deltas." — Oliver Dunbar, left, with brother Evan, sons of PM executive editor David Dunbar



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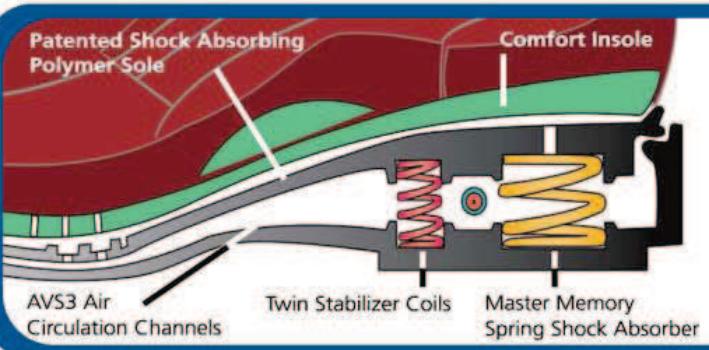
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within 3 mos.



Clinical Survey - Survey conducted of 152 Gravity Defyer customers using the guidelines of New York College of Podiatric Medicine. 73% male and 27% female.

WISH
LIST

02

Mypressi Twist Espresso Maker (\$170)

This travel-friendly espresso maker uses off-the-shelf nitrous-oxide cartridges to prepare the coffee—no power plugs needed.

05

Samsung DualView TL225 Camera (\$350)

Self-portraits have never been easier, thanks to a second, front-facing LCD screen on this 12-megapixel, 4.6x-optical-zooming compact camera.

03

Bosch SPS10 4-Volt Pocket Screwdriver (\$60)

What this fist-size lithium-ion 4-volt mini driver lacks in power it makes up for in portability—it weighs just a pound, making it ideal for small jobs such as hanging pictures and assembling furniture.

06

MSR Flex 4 System Cookset (\$160)

This campsite cooking set packs two pots and enough plates and insulated mugs for a hungry group of four or more into a backpack-friendly nested bundle.

01

Mountain Boy 6-Foot Toboggan (\$200)

The extra-large end curl on this all-family toboggan is big enough to hold an adult's foot, and its basswood finish is elegant enough to be displayed in the off-season.

04

Ardica Moshi Personal Power System (\$120)

This lithium-ion battery pack slips unobtrusively inside compatible jackets (like those from Mountain Hardwear, pictured) to keep wearers warm and charge their gadgets via a pocket-based USB cord.



Last year's music player at half price
still plays this year's music at full volume.

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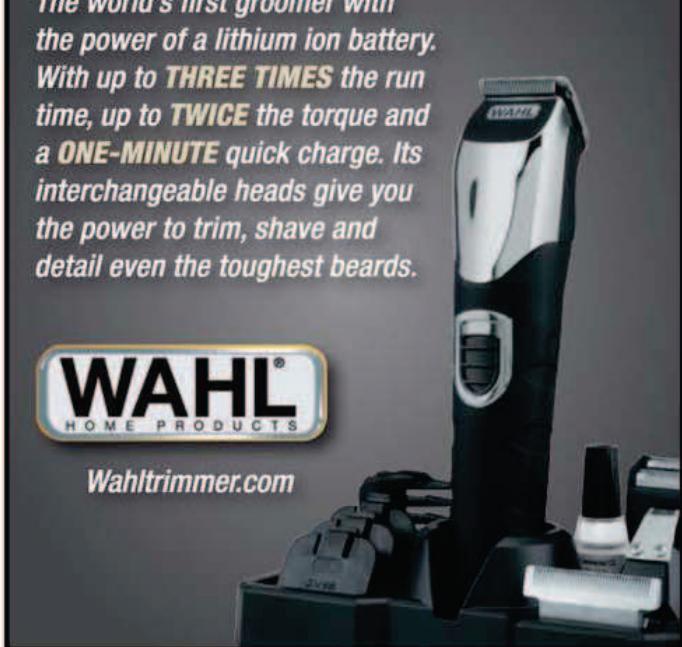
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2010

AUTOMOTIVE EXCELLENCE AWARDS

► The year 2009 may have been a tumultuous one, but despite bankruptcies and near bankruptcies, engineers still developed some of the best cars we've ever seen. American icons have returned, a wave of new hybrids is pointing the way to a more efficient future, and compact cars are proving small can be cool. We know, because PM's auto department has spent the past year evaluating new cars and trucks around the world. Testing cars is not only serious business, it's seriously fun too. Each year, we gather our findings and debate, sometimes quite passionately, which 10 cars, trucks and technologies are the most significant. The winners are presented here—in the Automotive Excellence Awards for 2010.

→ *by the editors*

PM TEST-DRIVEN VEHICLES

The Ford F-150 Raptor looks tough enough to run straight down the Baja Peninsula, race across the Mexican mainland and then continue roaring down through South America until it plows across Antarctica. It is the most extreme high-speed 4x4 pickup ever produced. It looks simply ferocious with its swollen flanks, aggressive stance, visibly rugged suspension pieces and thumping 35-inch-tall



Ford

BF Goodrich off-road tires. The powertrain is still pure F-150, with a 320-hp 5.4-liter V8 linked to a six-speed automatic, though an exclusive 400-hp 6.2-liter "Boss" V8 will soon become an option. Engineers widened the F-150's track by 7 inches with new upper and lower control arms. The lower arms are chamfered like a skidplate, so rocks can slide underneath without hanging the truck up. To allow the Raptor to glide over obstacles and take the punishment of hard landings, the Special Vehicle Team (SVT) chose

specifically tuned internal-bypass Fox Racing shocks. There's nothing exotic about how the Raptor moves over pavement. But the thrills off-road are mighty indeed—the truck is absolutely magical. Whoops, whoop-dees and whoop-dee-dos all get swallowed up by the Raptor's suspension with casual disdain. At speeds that would lead to jail time when practiced on

any interstate, the Raptor can cruise over yard-deep gullies as if they were speed bumps at a Wal-Mart. Amazingly, while all of the SVT's changes are designed to aid the Raptor's off-road ability, they don't exact a toll in truck utility. The Raptor is rated to tow 6000 pounds and carry a maximum payload of 1020 pounds. A truck that works as hard as it plays? Sign us up.

Ford's Special Vehicle Team—the same engineers who developed the Mustang Shelby GT500—transformed the F-150 pickup into the most capable high-speed 4WD truck ever produced. The Raptor team tuned the suspension on a brutal 62-mile loop in a remote part of the California desert.

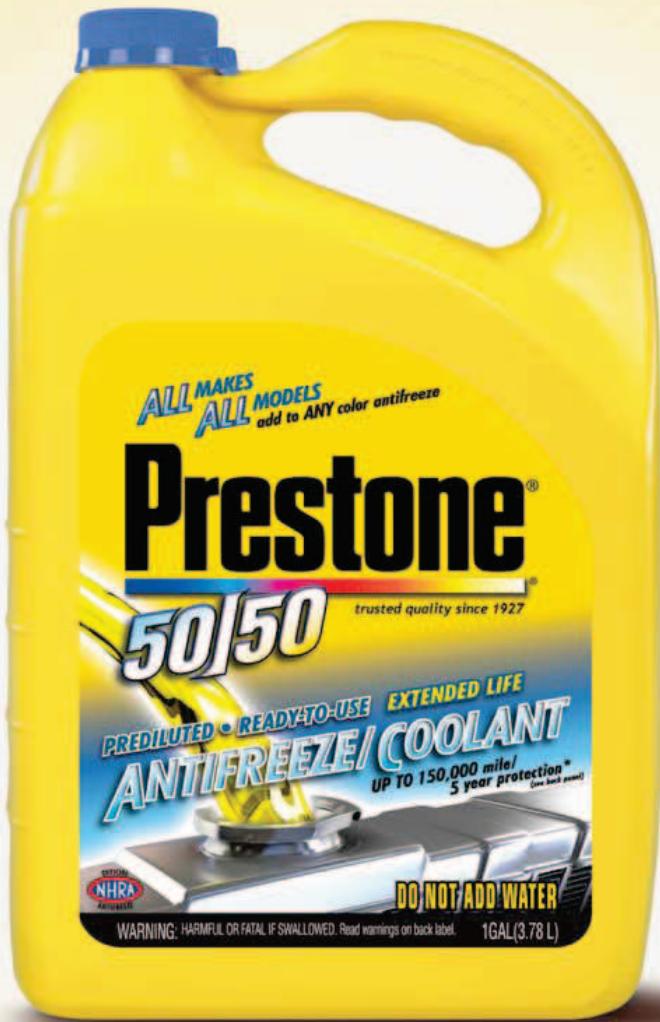
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ONLY PRESTONE IS PRESTONE

Few cars define efficient travel like the Toyota Prius. And the Prius has been the mpg leader—a title it has earned yet again with its 2010 model. A low (0.25) coefficient of drag is where the efficiency starts, but the real secret is in the refinements to Toyota's hybrid system. The 1.5-liter engine has been replaced with a torque-rich 1.8-liter unit that still operates with the late-intake-valve-closing Atkinson cycle. More low-end torque means the engine doesn't have to work as hard. The hybrid system uses the

same planetary continuously variable transmission (CVT) as before, but with a new twist. The main electric motor drive was downsized and produces less torque (153 lb-ft versus 295). But a reduction gearset that connects it to the gearbox allows that motor to spin faster. Consequently, it makes 80 peak hp, 13 more than before. The nickel-metal-hydride battery pack has a more effective cooling system too, which allows peak output to rise from 25 kilowatts to 27. And now, finally, Prius owners can hit an EV button and cruise for about a mile locked in electric drive. On a recent test, the car delivered a thrifty 52 mpg in the city—even better than the EPA's 51-mpg

rating. Toyota's hybrid system remains the benchmark. But the tech extends beyond the drivetrain with optional solar ventilation, radar-based cruise control and intelligent parking. Yet it's the driving dynamics that make the Toyota appealing to a wider audience. This is the first Prius that's actually fun to drive.

The Prius, with its 50-plus-mpg capability, is the most fuel-efficient car in America. And Toyota will raise that bar within two years. The plug-in version for 2012 will have an electric-only range of 12.5 miles thanks to lithium-ion batteries.

Fuel Efficiency

Toyota

PRIUS

BASE PRICE: \$22,000



Technical Innovation

Lexus

REMOTE TOUCH

As automobiles accumulate more and more advanced electronic functions, how do you control them? Newer systems attempt to access nearly every automotive function with a single-point controller. And every strategy has had drawbacks—except for Lexus's new Remote Touch. This haptic system works just like a computer mouse: You guide an arrow on the car's main screen and click a button at the controller's base with your thumb to make a selection. It offers subtle but effective force feedback to let the operator know when the cursor has crossed to a different function or onto a virtual button. And you can dial in exactly the amount of feedback you want. This brilliant system is the solution we've been waiting for. Remote Touch is only available on the Lexus HS250h and RX 350.

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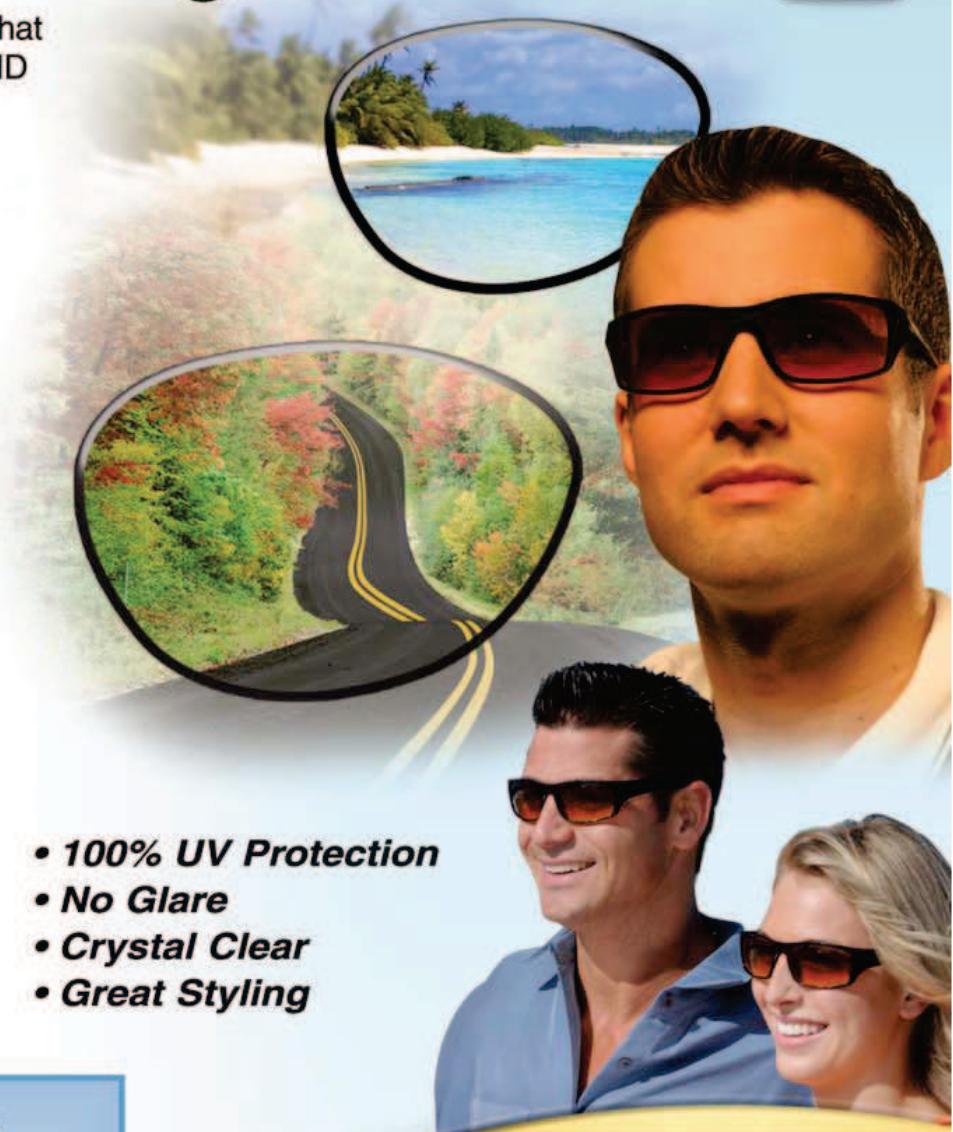
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3. **Mail:** Send a check or money order made out to "HD Ultra" for \$16.99 (includes S&H) plus *\$6.99 S&H for 2nd set to: HD Ultra Offer MEC, PO Box 4525, Pacoima, CA 91333.

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- **Great Styling**



Also available in Tortoise

Hyundai

GENESIS COUPE

BASE PRICE: \$22,750

Fun to
Drive

Hyundai has transformed its image—and its cars—in an amazingly short time. The Genesis sedan, introduced last year, proved the Korean company could produce Lexus-level luxury. This year's Genesis Coupe shows that Hyundai can deliver an exceedingly fun-to-drive sports coupe.

Hyundai's new Genesis Coupe returns rear-wheel-drive handling dynamics to budget-minded enthusiasts. Sporty cars in this Hyundai's price range are usually hot-rod versions of front-wheel-drive econoboxes. However, Hyundai adapted the rear-drive Genesis platform for this alluring driver's car. The

result is a sports coupe that can fend off cars costing thousands more. In fact, when we tested a Genesis Coupe against an Infiniti G37, the Hyundai nearly matched the Infiniti in every performance measure, and did so for \$15,000 less. The chassis feels taut and controlled, with steering responses that encourage the driver

to press harder into each corner, driving the tires right up to the edge of their capability. This is a car designed for canyon carving—especially when equipped with the Track package, which includes 19-inch wheels with summer tires, Brembo brakes, sport-tuned suspension and a limited-slip differential.

Hyundai's big V8 is not available—but the 306-hp V6 and the six-speed automatic is good for sub-six-second sprints to 60 mph. A 210-hp turbo four-cylinder is a less expensive and rather compelling alternative. The Genesis Coupe is more than just a sleek, fun-to-drive sports coupe. It's proof that Hyundai has developed world-class design, engineering and car-building expertise.



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*Driving while distracted can result in loss of vehicle control. Only use mobile phones and other devices, even with voice commands, when it is safe to do so.

Workhorse

Ford

TRANSIT CONNECT

BASE PRICE: \$21,475

For generations, the default vehicle for plumbers, contractors and delivery drivers has been the full-size van. The pressures of the economy, ever-increasing urban congestion and the fluctuating price of gasoline could move them to smaller rigs like the Transit Connect. The size is just right, with a low, flat floor that can be loaded through any of the three cargo doors. Powered by a thrifty four-cylinder engine driving the front wheels, the van returns 22 mpg city and 25 on the highway, is low enough to slide into many garages and can handle a 1600-pound payload. There's also Ford's Tool Link, a system that builds RFID sensors into the van so that at the press of a button the driver can see an inventory of all the tools aboard. The Transit Connect could also be a fun utility truck for the outdoor enthusiast—135 cubic feet can hold an awful lot of camping gear.

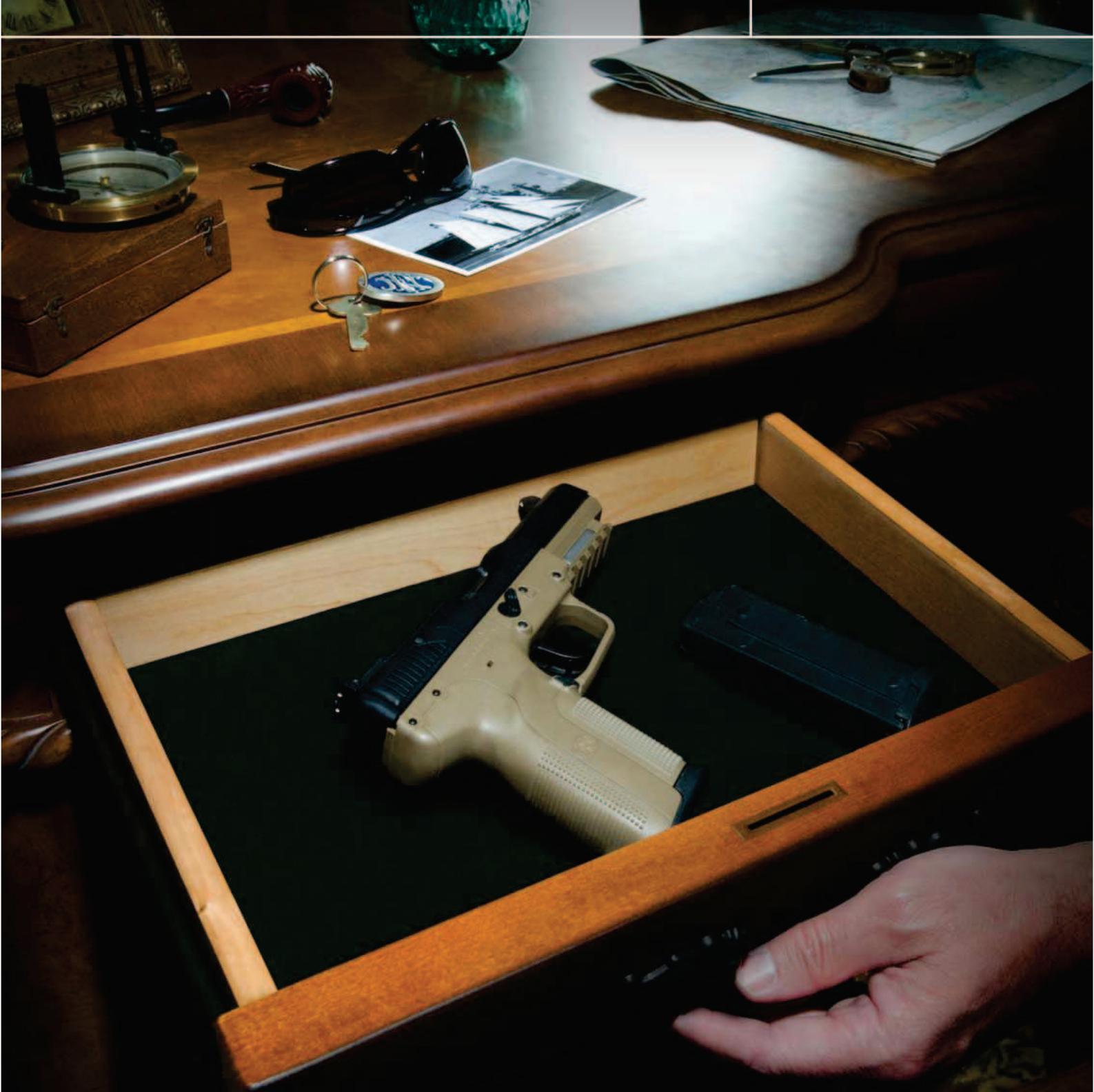


BMW 335d

Luxury BASE PRICE: \$43,900

In the future, the word "luxury" might describe automotive qualities quite different from what we imagine today. When sedate and sensible fuel sippers dominate the automotive landscape, luxury could define the ability to produce sports car acceleration with exemplary fuel economy. The BMW 335d is ahead of that curve. Under the hood is a twin-turbocharged 3.0-liter inline six-cylinder diesel, with a mammoth 425 lb-ft of torque that can return solid mileage. In fact, on a recent 390-mile PM test, we saw 33.6 mpg. It takes only one brief prod of the right pedal to know the BMW has an incredible motor. The rush of torque is not unlike an old-school big-block V8's. Reeling in

lesser cars is not only effortless, it's tantalizingly fun. And this diesel model fits right in with the rest of BMW's 3 Series lineup, offering fluid, organic steering and a chassis that encourages you to press on just as hard as the road and your bravado will allow. Yet this BMW rides comfortably and absorbs potholes with a muted "thump." Luxury cars don't have to be one-dimensional. The 335d blends luxury, performance, fuel economy and fun into one very rewarding package.



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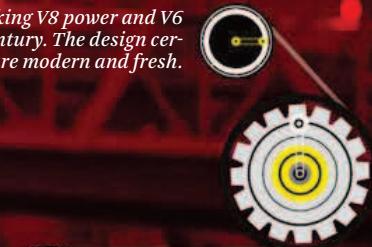
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After a painfully long eight-year hiatus, the Chevy Camaro returns packing V8 power and V6 efficiency wrapped around classic sheet metal pulled forward into the 21st century. The design certainly pays homage to the past, but the muscular lines of this Camaro are modern and fresh.

Chevrolet

CAMARO

BASE PRICE: \$22,245



Design

The success of a new car design, especially a sporty one, depends on its ability not just to turn heads, but to inspire an almost primal lust in everyone from a college kid to his grandfather—hitting all the age groups in between. The new Camaro does just that—and it's become one of the few cars outside the supercar

ranks that will almost always elicit a conversation at the gas pumps. Under the watch of GM design boss Ed Welburn, Chevy imagined the new Camaro as a thoroughly modern take on the 1967 original. And it looks amazingly close to the 2006 concept car. GM engineers somehow avoided the compromises that tend to dilute a designer's original vision as it makes its way into production. The inset front grille and the

outboard round headlights offer a real link to that first Camaro, yet the big wheels and taut proportions perfectly convey 21st-century muscle. Good design extends to the interior too: The view through the windshield is 1960s cool, yet it's the subtleties that make this car feel so right. Of course, a Camaro wouldn't feel right at all if

there wasn't some serious firepower under the hood. The top-dog SS models have a big 422-hp 6.2-liter V8, and even the base cars receive a potent V6 that returns 30 mpg highway. The real triumph is that all the Camaro's performance and intelligent design can be had for just a tick over \$20,000. That's a bargain.

**“ I used to think it was
just a phase, until I had ‘the talk’
with my doctor. ”**



Your Doctor Talks to Men About ED Every Day

Actually, erectile dysfunction (ED) is more than just a phase. It's a common medical condition affecting millions of men just like you. But your doctor can help.



Doctor portrayal.



Keys to Opening Up to Your Doctor

The hardest part about having ‘the talk’ is getting those first few words out. Here are some ideas to help you break the ice when your doctor asks how everything’s going:

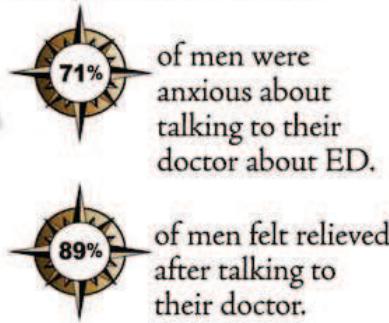
The Direct Approach:
“I have trouble sometimes
in bed. Could it be ED?”

The Indirect Approach:
“Is it true age affects
sexual performance?”

The Silent Approach:
Just hand this ad to your
doctor, he’ll take it from there.

Running the Numbers

Did you know half of all guys over 40 have some form of ED? Here are some numbers to keep in mind from a recent survey of men with ED:



Tell Me More

To learn more about VIAGRA for the treatment of ED, and ED in general, visit viagra.com today. You'll find an online sexual health quiz, videos of guys with ED who've had the VIAGRA Talk and other helpful information.

Over 20 million men have already had their VIAGRA Talk. Isn't it time you had yours?

Important Safety Information

We know that no medicine is for everyone. Don't take VIAGRA if you take nitrates, often prescribed for chest pain, as this may cause a sudden unsafe drop in blood pressure.

Talk with your doctor first. Make sure your heart is healthy enough to have sex. If you have chest pain, nausea, or other discomforts during sex, seek medical help right away.

In the rare event of an erection lasting more than four hours, seek immediate medical help to avoid long-term injury.

In rare instances, men who take PDE5 inhibitors (oral erectile dysfunction medicines, including VIAGRA) reported a sudden decrease or loss of vision, or sudden decrease or loss of hearing. It is not possible to determine whether these events are related directly to these medicines or to other factors. If you experience any of these symptoms, stop taking PDE5 inhibitors, including VIAGRA, and call a doctor right away.

The most common side effects of VIAGRA are headache, facial flushing, and upset stomach. Less common are bluish or blurred vision, or being sensitive to light. These may occur for a brief time.

VIAGRA does not protect against sexually transmitted diseases including HIV.

Please see Important Facts for VIAGRA on the following page or visit viagra.com for full prescribing information.

For free information, including questions to ask your doctor, call 1-888-4VIAGRA (1-888-484-2472).

VIAGRA®
(sildenafil citrate) tablets

IMPORTANT FACTS

VIAGRA® (sildenafil citrate) tablets

(vi-AG-rah)

IMPORTANT SAFETY INFORMATION ABOUT VIAGRA

Never take VIAGRA if you take any medicines with nitrates. This includes nitroglycerin. Your blood pressure could drop quickly. It could fall to an unsafe or life-threatening level.

ABOUT ERECTILE DYSFUNCTION (ED)

Erectile dysfunction means a man cannot get or keep an erection. Health problems, injury, or side effects of drugs may cause ED. The cause may not be known.

ABOUT VIAGRA

VIAGRA is used to treat ED in men. When you want to have sex, VIAGRA can help you get and keep an erection when you are sexually excited. You cannot get an erection just by taking the pill. Only your doctor can prescribe VIAGRA.

VIAGRA does not cure ED.

VIAGRA does not protect you or your partner from STDs (sexually transmitted diseases) or HIV. You will need to use a condom.

VIAGRA is not a hormone or an aphrodisiac.

WHO IS VIAGRA FOR?

Who should take VIAGRA?

Men who have ED and whose heart is healthy enough for sex.

Who should NOT take VIAGRA?

- If you ever take medicines with nitrates:
 - Medicines that treat chest pain (angina), such as nitroglycerin or isosorbide mononitrate or dinitrate
- If you use some street drugs, such as "poppers" (amyl nitrate or nitrite)
- If you are allergic to anything in the VIAGRA tablet.

BEFORE YOU START VIAGRA

Tell your doctor if you have or ever had:

- Heart attack, abnormal heartbeats, or stroke
- Heart problems, such as heart failure, chest pain, or aortic valve narrowing
- Low or high blood pressure
- Severe vision loss
- An eye condition called retinitis pigmentosa
- Kidney or liver problems
- Blood problems, such as sickle cell anemia or leukemia
- A deformed penis, Peyronie's disease, or an erection that lasted more than 4 hours
- Stomach ulcers or any kind of bleeding problems

Tell your doctor about all your medicines. Include over-the-counter medicines, vitamins, and herbal products. Tell your doctor if you take or use:

- Medicines called alpha-blockers to treat high blood pressure or prostate problems. Your blood pressure could suddenly get too low. You could get dizzy or faint. Your doctor may start you on a lower dose of VIAGRA.
- Medicines called protease inhibitors for HIV. Your doctor may prescribe a 25 mg dose. Your doctor may limit VIAGRA to 25 mg in a 48-hour period.
- Other methods to cause erections. These include pills, injections, implants, or pumps.

POSSIBLE SIDE EFFECTS OF VIAGRA

Side effects are mostly mild to moderate. They usually go away after a few hours. Some of these are more likely to happen with higher doses.

The most common side effects are:

- Headache
- Feeling flushed
- Upset stomach

Less common side effects are:

- Trouble telling blue and green apart or seeing a blue tinge on things
- Eyes being more sensitive to light
- Blurred vision

Rarely, a small number of men taking VIAGRA have reported these serious events:

- Having an erection that lasts more than 4 hours. If the erection is not treated right away, long-term loss of potency could occur.
- Sudden decrease or loss of sight in one or both eyes. We do not know if these events are caused by VIAGRA and medicines like it or caused by other factors. They may be caused by conditions like high blood pressure or diabetes. If you have sudden vision changes, stop using VIAGRA and all medicines like it. Call your doctor right away.
- Sudden decrease or loss of hearing. We do not know if these events are caused by VIAGRA and medicines like it or caused by other factors. If you have sudden hearing changes, stop using VIAGRA and all medicines like it. Call your doctor right away.
- Heart attack, stroke, irregular heartbeats, and death. We do not know whether these events are caused by VIAGRA or caused by other factors. Most of these happened in men who already had heart problems.

If you have any of these problems, stop VIAGRA. Call your doctor right away.

HOW TO TAKE VIAGRA

Do:

- Take VIAGRA only the way your doctor tells you. VIAGRA comes in 25 mg, 50 mg, and 100 mg tablets. Your doctor will tell you how much to take.
- If you are over 65 or have serious liver or kidney problems, your doctor may start you at the lowest dose (25 mg).
- Take VIAGRA about 1 hour before you want to have sex. VIAGRA starts to work in about 30 minutes when you are sexually excited. VIAGRA lasts up to 4 hours.

Don't:

- Do not take VIAGRA more than once a day.
- Do not take more VIAGRA than your doctor tells you. If you think you need more VIAGRA, talk with your doctor.
- Do not start or stop any other medicines before checking with your doctor.

NEED MORE INFORMATION?

- This is only a summary of important information. Ask your doctor or pharmacist for complete product information OR
- Go to www.viagra.com or call (888) 4-VIAGRA (484-2472).

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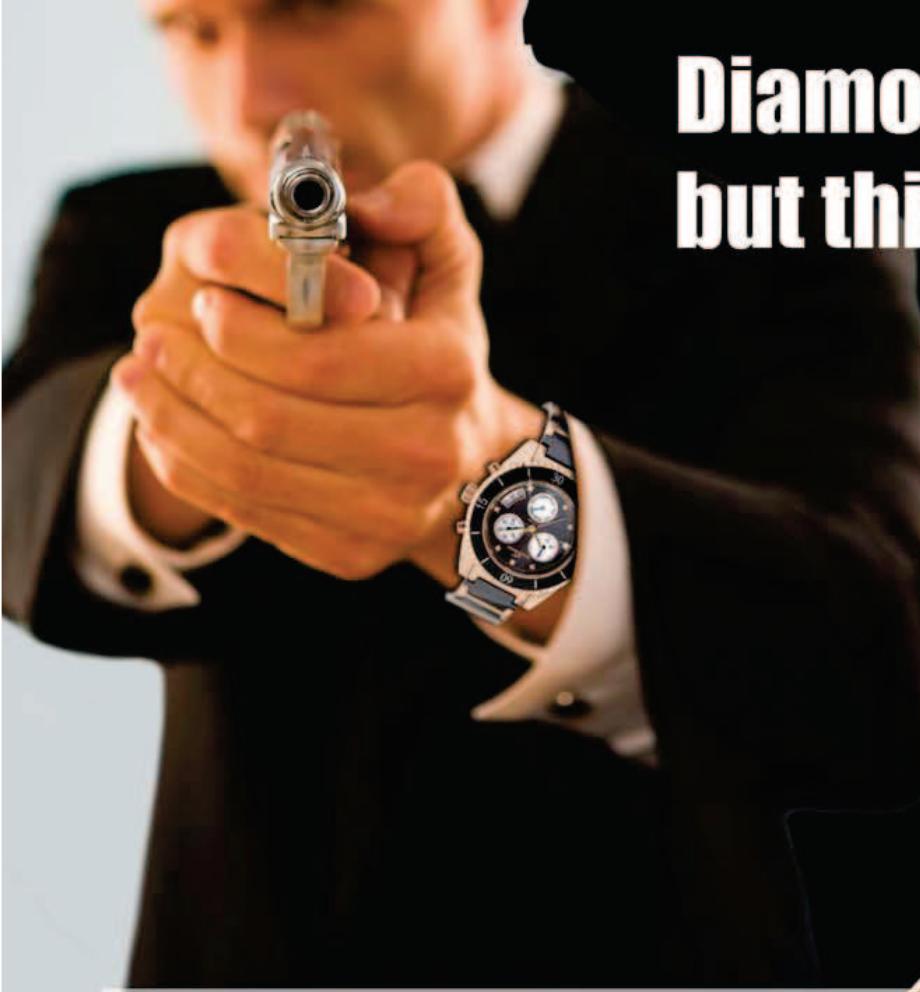
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Long before the term "crossover" became synonymous with rugged, car-based utility wagons, Subaru had the Outback. To many, that original 1995 Outback was the first real crossover, blending the best attributes of an SUV with the nimble handling of a traditional car and the capability of Subaru's rally-bred all-wheel-drive expertise. This latest model only widens that capability envelope. Riding on beefy tires, and with a suspension tall enough to produce a Hummer-humbling



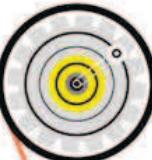
Subaru

OUTBACK

BASE PRICE: \$22,995

8.7 inches of ground clearance, the Outback is not a corner carver. Instead, the Outback is a sweet-natured wagon with poised road manners that scrambles effortlessly along dirt roads and up some pretty difficult trails. With the wheelbase stretched over the previous version's, rear-seat comfort is substantially improved. Fold that seat down, and the Outback can swallow 71.3 cubic feet of camping gear, gardening supplies or pinewood planks. Subaru owners are determined to wring every last ounce of value from their purchases—there's plenty of value and versatility in this new Outback.

Versatility



Kia

SOUL

BASE PRICE: \$13,300

Small cars don't have to compromise functionality or performance. The Kia Soul is a fun, sporty compact at a very reasonable price.



Value

It's not often that a car's

moniker actually matches its personality. But for the Kia Soul, the name fits. Sure, it's one of the least expensive new cars on the market, but it packs quite a lot of substance into that bargain-basement price tag. Inside, the materials used are one solid notch above the class. Kia offers two engines. We prefer the more potent 142-hp 2.0-liter inline Four that comes standard on Sport models. The Soul Sport is surprisingly fun to drive. The firm suspension and robust motor make short work of switchbacks. And yet, on a recent 300-mile fuel-economy marathon test drive, the Kia Soul Sport returned a very solid 31.2 mpg. When three testers piled into the back seat they found plenty of comfort—even on longer trips. And with those seats folded, the Kia can handle 53.4 cubic feet of cargo. When you back up the head-turning styling with grin-inducing performance and a modest price, you've got one very smart buy.



American Revolution Silver Dollars FOUND!

Authentic coins from 1783 – the year we won our independence!

A fishing expedition off the southern coast of the U.S. recently netted a cache of American silver dollars lost at the bottom of the sea for over 200 years—and upon closer examination it was discovered that many of these coins are dated 1783—the year we won our freedom!

The Silver Dollar of our Founding Fathers.

George Washington, Thomas Jefferson and Ben Franklin could have carried these same coins in their pockets at the time our country was born. Jefferson recommended the Continental Congress adopt this silver dollar as the country's FIRST silver dollar. Congress agreed. The rest is history. And now that they are available to the American public, the coin of our founding fathers is *tangible history you can secure for your very own.*

Now, through this discovery, you can own a set of TWO of these historic treasures — at a truly affordable price! Authentic items from the time of the Revolutionary War are seldom found or can be seen only in museums. Over the last 225 years most colonial American silver dollars have been lost or melted down for their precious silver. Containing a hefty 27 grams of 90.3% silver these coins were real money back then—and real money today. They currently sell elsewhere for as high as \$295 each. But because of this historic discovery and our exclusive negotiations, for a limited time, you can own not just one of these coins of our Founding Fathers, but a set of TWO 1783 Silver Dollars—for our Guaranteed best price of only \$149! That's less than \$75 for each Silver Dollar! Both coins were hand selected for their detail, one featuring a visible date on its front, and the other the Spanish Coat of Arms on its reverse.



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The 21st-century muscle car wars have a new superpower to contend with: the Mustang Shelby GT500, the baddest of all Mustangs. This 540-hp street terror will rocket through the quarter-mile in just 12.6 seconds—trouncing its Detroit competitors by a wide margin. Even better, Ford's Special Vehicle Team made sure the GT500 sticks to the corners and stops like a proper sports car. The chassis is wonderfully competent and makes it just as fun to attack the back roads as it is to tear

down the quarter-mile. The steering is quick, light and devoid of slop. This confident handling wasn't achieved by sacrificing the visceral thrill we want in a ponycar, either. Ford has quieted the supercharger, so the burbly V8 exhaust is more audible. The twin-plate clutch is now much lighter and it engages smoothly, a

perfect ally to that cue-ball shifter and the well-defined gates it engages. The brakes are always reassuring, and the pedal is close enough to the throttle for easy heel-and-toe work. And somehow lurid, sideways, tire-smoking burnouts never, ever get old in this car. Part of the magic here is in the details. The

designers employed a deft hand, including small, subtle details like stitched-in seat stripes and an aggressive chin spoiler. Sure, the GT500's near \$50,000 price is in Corvette territory. But this is a thrill ride that's worth every penny. Is this the best Mustang ever? Oh yeah.

Performance

Ford

MUSTANG SHELBY GT500

BASE PRICE: \$47,175

The GT500's menacing maw gobbles air to feed a hungry, supercharged 5.4-liter V8. This is old-school Detroit muscle, yet the Mustang offers a level of refinement previous hot Fords have lacked. The GT500's chassis is more sophisticated than any Mustang in the car's 46-year history.



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Hear it in your home for 30 days. And call to ask about making **12 easy payments**, with no interest charges from Bose.* Use the risk-free trial to discover how easy it can be to enjoy all your music – including your computer music. Wirelessly. With the performance quality of Bose, the most respected name in sound.



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THE NEW MACHINE AGE

BY GLENN HARLAN REYNOLDS
ILLUSTRATION BY NATHAN HUANG

For some time now, futurists have been talking about a concept called the Singularity, a technological jump so big that society will be transformed. If they're right, the Industrial Revolution—or even the development of agriculture or harnessing of fire—might seem like minor historical hiccups by comparison. The possibility is now seeming realistic enough that scientists and engineers are grappling with the implications—for good and ill.

When I spoke to technology pioneer and futurist Ray Kurzweil (who popularized the idea in his book *The Singularity Is Near*), he put it this way: "Within a quarter-century, non-

FUTURISTS SAY THE SINGULARITY—WHEN COMPUTERS OVERTAKE HUMANS—IS COMING. WHAT HAPPENS NEXT?

biological intelligence will match the range and subtlety of human intelligence. It will then soar past it."

Even before we reach that point, Kurzweil and his peers foresee breathtaking advances. Scientists in Israel have developed tiny robots to crawl through blood vessels attacking cancers, and labs in the United States are working on similar technology. These robots will grow smaller and more capable. One day, intelligent nanobots may be integrated into our bodies to clear arteries and rebuild failing organs, communicating with each other and the outside world via a "cloud" network. Tiny bots might attach themselves to neurons in the brain and add their processing power—and that of other computers in the cloud—to ours, giving us mental resources that would dwarf anything available now. By stimulating the optic, auditory or tactile nerves, such nanobots might be able to simulate vision, hearing or touch, providing "augmented reality" overlays identifying street names, helping with face recognition or telling us how to repair things we've never seen before.

Scientists in Japan are already producing rudimentary nanobot "brains." Could it take decades for these technologies to come to fruition? Yes—but only decades, not centuries. The result may be what Kurzweil calls "an intimate merger between the technology-creating species and the technological evolutionary process it spawned."

If scientists can integrate tiny robots into the human body, then they

NANOROBOTS FLOATING AROUND IN YOUR BLOODSTREAM COULD KEEP YOUR CORONARY ARTERIES FROM CLOGGING, BUT THEY ALSO COULD RELEASE DRUGS ON COMMAND, MAKING YOU, SAY, LITERALLY LOVE BIG BROTHER.

can build tiny robots into, well, everything, ushering in an era of “smart matter.” Nanobots may be able to build products molecule-by-molecule, making the material world look a lot like the computer world—with just about everything becoming smart, cheap and networked to pretty much everything else, including your brain.

It's almost impossibly futuristic-sounding stuff. But even that scenario is just the precursor to the Singularity itself, the moment when, in Kurzweil's words, “nonbiological intelligence will have access to its own design and will be able to improve itself in an increasingly rapid redesign cycle.” Imagine computers so advanced that they can design and build new, even better computers, with subsequent generations emerging so quickly they soon leave human engineers the equivalent of centuries behind. That's the Singularity—and given the exponential acceleration of technological change, it could come by midcentury.

But Is It for Real?

It seems like a tall order, but lots of people think that such predictions are likely to come true. I asked science-fiction writer John Scalzi about Singularity issues and he pointed out that the Skype video we were using to chat would have seemed like witchcraft a few centuries earlier. Profound technological changes once took millennia, then centuries, and then decades. Now they occur every few years. The iPhone and pocket-size 12-megapixel digital cameras would have seemed amazing a decade ago. Web browsers are only about 15 years old. People (including my wife) have computers implanted in their bodies already, in the form of defibrillators, pacemakers and other devices.

Still, I'm describing a world in which nanotechnology makes us

(nearly) immortal, in which robots can make almost any object from cheap raw materials (basically, dirt) and in which ordinary people are smarter than Einstein thanks to brain implants—but still nowhere near as smart as fully artificial intelligences. That's a world that's hard to imagine.

And what we do imagine can sound either good or bad. On the upside, what's not to like about being super-smart and healthy, with access to most products essentially for free? On the downside, could always-on links from our brains to the computing cloud lead to *Star Trek*'s über-totalitarian Borg collective or something equally scary? And, what happens to those computer-brain interfaces and nanobots when they're taken over by the descendants of the Conficker worm? Now there's an argument for strong antivirus software.

Dramatically enhancing human capabilities for good, alas, also means enhancing human capabilities for evil. That's something famed computer science professor and writer Vernor Vinge warns about: technology that could, as he wrote in his novel *Rainbows End*, “put world-killer weapons into the hands of anyone having a bad-hair day.” Then there's the mind-control problem. Nanobots floating around in your bloodstream could keep your coronary arteries from clogging, but they also could release drugs on command, making you, say, literally love Big Brother. Knowing what we know about human history, do such abuses seem terribly unlikely?

Of course, the problem may never come up. Vinge, who originated the Singularity idea, has written about why it may never arrive—though he's

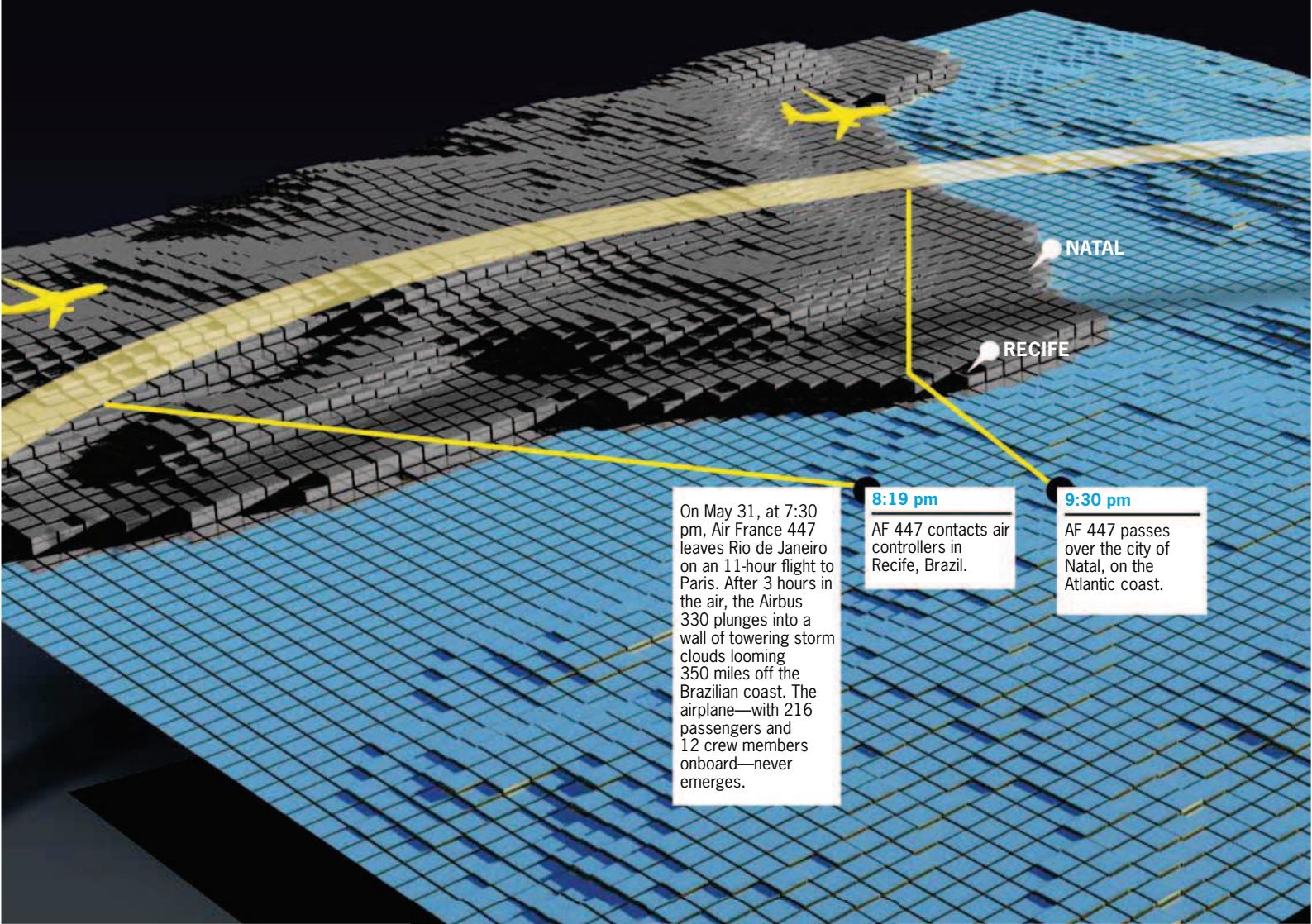
betting the other way. So what can we do now to affect how things turn out? Some people are trying. The Foresight Institute has published guidelines for developing nanotechnology, such as a ban on self-replicating nanobots that function independently (potentially turning the whole world into more nanobots, something known in the trade as the gray-goo problem) and sharp limitations on weapons-related nanotech research. Researchers in artificial intelligence are working on guidelines for producing “friendly AI” that would be well-disposed toward humans as part of their programming, thus foreclosing any pesky robotic world-domination ambitions. NASA, Google and others have even started something called the Singularity University to study ways to avoid problems while still reaping the benefits. Some have suggested that we ought to go slow on the so-called GRAIN technologies (Genetics, Robotics, Artificial Intelligence and Nanotechnology). Sun Microsystems' Bill Joy has even called for “relinquishing” some technologies he sees as dangerous.

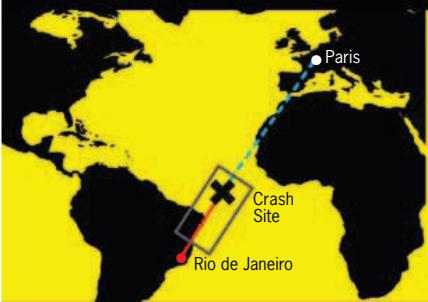
But I wonder if that's such a good idea. Destructive technologies generally seem to come along sooner than constructive ones—we got war rockets before missile interceptors, and biological warfare before antibiotics. This suggests that there will be a window of vulnerability between the time when we develop technologies that can do dangerous things, and the time when we can protect against those dangers. The slower we move, the longer that window may remain open, leaving more time for the evil, the unscrupulous or the careless to wreak havoc. My conclusion? Faster, please. **PM**

ANATOMY OF A PLANE CRASH

THE AVIATION INDUSTRY'S SAFETY RECORD HAS NEVER BEEN BETTER, BUT THE MYSTERIOUS LOSS OF AN AIRLINER IS CHALLENGING EFFORTS TO PREVENT TRAGEDIES BEFORE THEY HAPPEN.

BY JEFF WISE
INFOGRAPHIC BY AXEL DE ROY

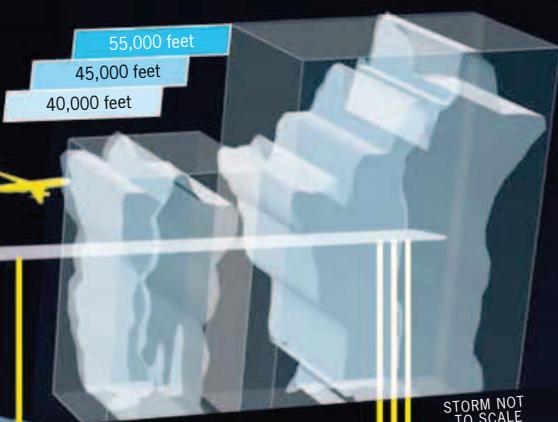




SEVEN MILES ABOVE THE EMPTY EXPANSE OF THE SOUTH ATLANTIC OCEAN, on May 31, 2009, an Air France A330 passenger jet cut through the midnight darkness. The plane had taken off 3 hours earlier, climbing from Rio de Janeiro on a northeast heading, its navigation computers hewing to a great-circle route that would take the flight 5680 miles to Paris.

At 10:35 pm local time, one of the co-pilots on the flight deck radioed Atlantico Area Control Center in Recife, Brazil, and announced that the plane had just reached a navigation waypoint called INTOL, situated 350 miles off the Brazilian coast. The waypoint lay just shy of the Intertropical Convergence Zone, a meteorological region along the equator famous for intense

The airplane flies through a small storm, but its radar cannot detect a far more violent, multicell system lurking beyond. At peak intensity, the thunderstorm soars more than 3 miles above AF 447 and buffets the airliner with updrafts approaching 70 mph.



10:30 pm
AF 447 reaches INTOL GPS navigation waypoint.

10:35 pm
AF 447 radios final verbal message (to Atlantico Area Control Center): "Air France Four Four Seven, thank you."

An automatic messaging system onboard AF 447 transmits a torrent of text messages via satellite to the airline's headquarters in Paris. The 24 encoded texts, reported in just 4 minutes, provide clues about the flight's final moments.

11:10 pm
The flight control computer receives unreliable sensor data; in response, autopilot disconnects.

11:11-11:12 pm
Speed-limit settings shut down. Safeguards that help pilots prevent rudder damage now fail.

11:13-11:14 pm
Loss of backup instruments that measure pitch angle and velocity. Loss of all internal reference, including heading, vertical speed, flight-path vector and position. Last transmission: a vertical speed advisory, triggered when the cabin drops faster than 30 feet per second.

ANATOMY OF A PLANE CRASH

thunderstorms. Staff at Atlantico acknowledged the transmission and received the airplane's reply: "Air France Four Four Seven, thank you."

It was the second time within the past 12 hours that the jet, F-GZCP, had crossed this stretch of ocean, having flown the Paris-to-Rio leg with only 2 hours to refuel and load passengers before departing again. Such was the lot of the four-year-old long-haul plane: a repeated cycle of flight and turnaround, as rhythmic and uneventful as the phases of the moon. But the routine was about to be broken.

After receiving AF 447's transmission, Atlantico asked for the estimated time it would take the aircraft to reach the TASIL waypoint, which lies on the boundary of the Atlantico and the Dakar Oceanic control areas. At that point communication would pass from Brazil to Senegal. AF 447 did not reply. The controller asked again. Still, there was no reply. The controller asked a third and fourth time, then alerted other control centers about the lapse.

According to the flight plan filed by AF 447, the plane should have crossed into Dakar Oceanic at 11:20 pm, at which point the flight crew would have made radio contact with Dakar to confirm their position. They didn't. They also failed to contact the Cape Verde controller, whose airspace they were supposed to enter at 12:43 am. As time went on, controllers along the aircraft's route began to worry that the problem was more than just a communications breakdown.

By 3:47 am, the flight should have appeared on the radar screens of Portuguese air traffic controllers. It didn't. An hour later, Air France contacted the Bureau d'Enquêtes et d'Analyses

pour la Sécurité de l'Aviation Civile (BEA), the French equivalent of the United States' National Transportation Safety Board. By 8 am, French authorities officially reached what had become a grim, unavoidable conclusion: Air France 447 had disappeared.

VANISHING WITHOUT A TRACE

is not supposed to happen in this day and age. The globe is crisscrossed by constant ship and air traffic. A constellation of satellites orbits overhead, and communication is nonstop. Yet, for a few days in early June, it seemed that the impossible had happened. Air France 447 and the 228 people onboard were simply gone. There was no distress call or wreckage; there were no bodies.

Within hours, the French government deployed a search-and-rescue airplane near the TASIL waypoint. Over the next few days a flotilla of ships and aircraft arrived to assist the search operation, including a French nuclear submarine and a research vessel with an unmanned deep-water submersible that were dispatched to find the flight data recorder, or black box.

Yet for days nothing was found. The only clues to the plane's fate were automatic messages that the onboard maintenance computer transmitted by a datalink system called the Aircraft Communications Addressing and Reporting System (ACARS). The system transmits text messages via satellite to ground stations, which then forward them on landlines to the intended destination. In just a 4-minute span, the system had broadcast 24 reports to Air France's dispatch center in Paris, each concerning problems with

A search party from the Brazilian navy recovers the largest physical clue in the Air France 447 mystery: the tail fin, which likely broke off the airplane when it hit the water.



BUILDING A SAFER AIRPORT



Flight 4590
July 2000

AT 2:42 PM ON JULY 25, 2000, Air France 4590 roared down runway 26R at Charles de Gaulle International Airport in Paris, bound for New York with 109 passengers and crew onboard. As the supersonic jet accelerated for takeoff, it ran over a 17-inch-long strip of titanium that had fallen off the thrust reverser of a recently departed DC-10. The metal shredded one of the Concorde's tires, and the flying pieces ruptured and ignited a fuel tank. The plane crashed 2 minutes later, killing all onboard and four people on the ground. Investigators found the runway was uncheckered for 12 hours before the crash. The accident highlighted a paradox: Some of the worst threats to aviation, including debris, vehicles and other aircraft, are located on the ground.

1. Broadcast Tower

The FAA's Airport Surface Detection Equipment-X integrates data from an inbound plane's GPS unit and the transponder signals from ground vehicles and other planes in the air to generate a continuously updated map of all airport traffic. Remote towers capture and relay information from airplanes in flight. ASDE-X, which alerts air traffic controllers to an impending conflict, is already in use at 20 U.S. airports; the FAA plans to install it in 15 more by 2011.

2. Cockpit Digital Maps

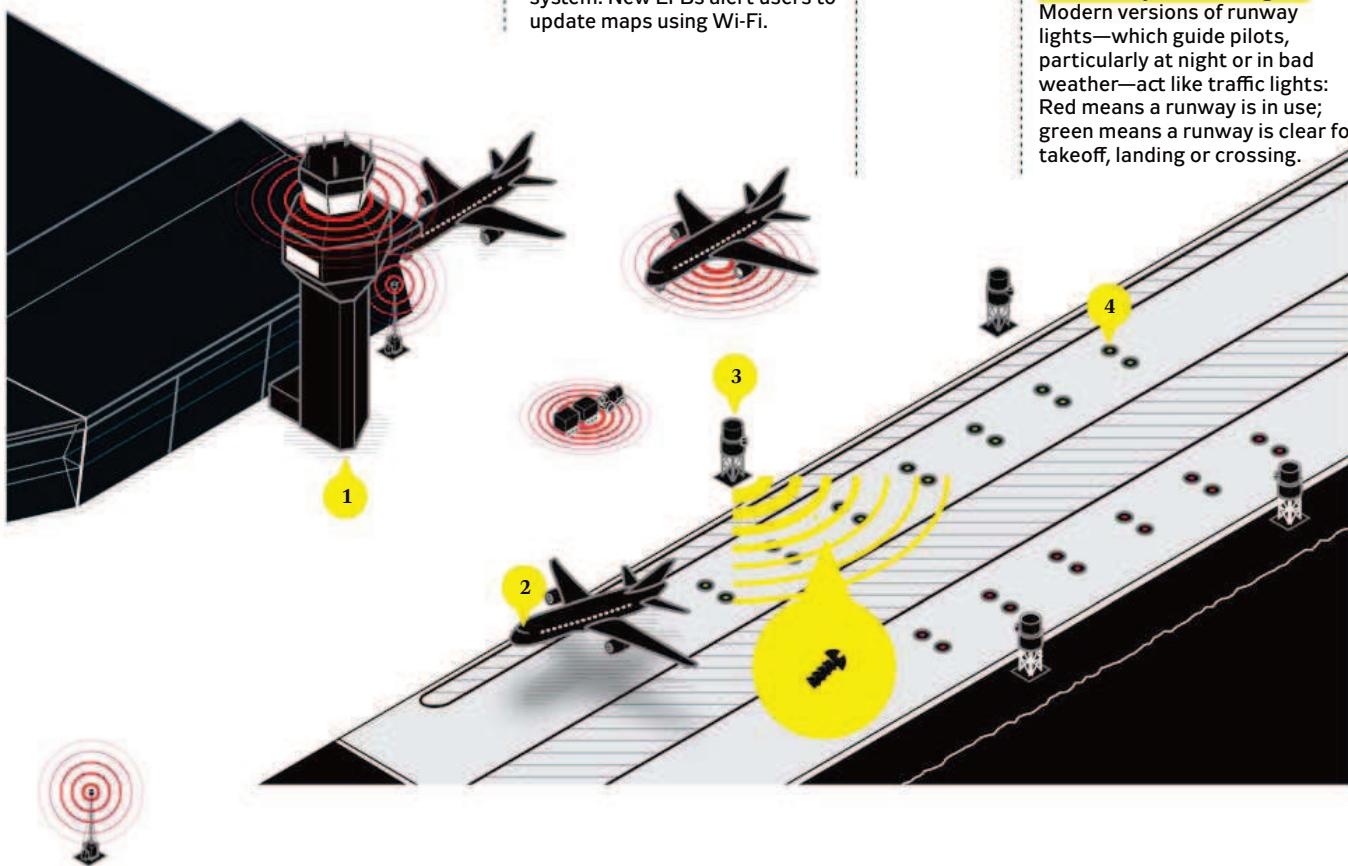
Paper maps keep pilots out of trouble, but they need to be updated regularly. Digital maps of airports and the surrounding areas are more easily amended to include new obstacles and infrastructure. Pilots carry laptop-size computers called Electronic Flight Bags that plug into the cockpit navigation system. New EFBs alert users to update maps using Wi-Fi.

3. High-Frequency Radar

Detectors use sensitive radar with wavelengths as tight as a millimeter to spot debris as small as a bolt that could cause crashes; some systems have cameras that compare images to a database of common objects, distinguishing grass or paper from more dangerous obstacles.

4. Runway Status Lights

Modern versions of runway lights—which guide pilots, particularly at night or in bad weather—act like traffic lights: Red means a runway is in use; green means a runway is clear for takeoff, landing or crossing.



BUILDING A SAFER COCKPIT

Flight 255
August
1987

NORTHWEST 255 had just taken off from Detroit on Aug. 16, 1987, when it began rocking side to side. The plane clipped a building and caught fire before sliding under a railroad embankment and two highway overpasses (right). The crash, which killed all 154 onboard and two bystanders, occurred because the MD-82's pilots did not extend slats on the leading edge and flaps on the trailing edge of the wings to generate extra lift. The manufacturer recommended that airlines modify their MD-80 cockpit checklists; U.S. carriers did so, but not all foreign carriers. In 2008 a Spanair MD-82 crashed in Madrid because of a similar mistake, killing 154—showing that failure to modify procedures in response to crashes, close calls and government advisories can cost lives. Here are other changes in the cockpit that reduce chance of pilot error. — MARK HUBER



1. Make Two-Person Altitude Calls

To prevent planes from dropping below assigned altitudes—which increases the risk of midair collisions—the co-pilot sets the altitude, called “pointing,” and the pilot confirms that it is correct.

2. Retract Speed Brakes

Failing to retract speed brakes—panels that increase wing-surface area—in an aborted landing means an aircraft can't climb quickly. Many airlines require co-pilots to verify speed-brake status if the plane misses a landing.

3. Know Speed Limits

Flaps, which are extended to allow airplanes to remain aloft at slower speeds during takeoff and landing, can suffer motor damage if they are deployed while the airplane is traveling too fast. In addition to memorizing these speed limits, co-pilots at some airlines are required to call them out as the airplane prepares to land.

4. Confirm Spoiler Deployment

Like speed brakes, spoilers are wing surfaces that diminish lift and are needed during landing, when an airplane must quickly shed speed. It is the co-pilot's job to confirm that spoilers have been deployed during a landing to prevent the plane from overshooting the runway.

Enhanced and synthetic vision systems (left) blend GPS information with a topographical database to create a moving digital map of unseen terrain and hazards.



subsystems onboard the aircraft.

At 11:10 pm, about 35 minutes after AF 447's last verbal communication, the system sent a message that the autopilot had disconnected. Seconds later, it reported that the flight control system was unable to determine the aircraft's correct speed. Subsequent messages cited a cascade of other malfunctions. At 11:14 pm, the final message reported that the airliner's cabin either had depressurized, was moving with high vertical velocity, or both.

ACARS messages are transmitted in a dense alphanumeric code and are used for airplane maintenance, not real-time monitoring of flights by dispatch centers. When investigators realized that the plane was lost, they scrutinized the messages. The story the transmissions told was tantalizing, but inconclusive. Did the error messages suggest a fault in the sensors, or was the flight management system somehow fatally corrupted—perhaps because of a midair lightning strike?

The absence of clues causes concerns that reach beyond the AF 447 investigation. Was the crash a result of pilot error, an unexpected breakdown of vital equipment or a combination of both? Without answers, there is no way to guarantee that another airliner won't suffer the same fate.

ALL THE ATTENTION GIVEN TO A crash like Air France 447's can obscure an important truth: Commercial air travel is incredibly safe—and getting safer. In 2008, the U.S. fatality rate was fewer than one death per nearly 11 million passenger trips. This impressive record is the result of more than a century of incremental improvements that have been amassed through painstaking forensic analysis.

After each plane crash, investigators study the wreckage, analyze flight data and examine clues regarding flight conditions. Once they have determined a

cause, they often help create recommendations that prevent the problem from recurring.

The FAA is determined to cut the already minuscule airliner fatality rate in half by 2025. With this in mind, the agency recently developed a new approach to make safety improvements. In 2007, it began working with airlines to sift through the masses of data that planes record about their normal flight operations, looking for safety improvements that could preempt accidents before they happen, instead of learning these lessons after a plane crash occurs.

The sophistication of aircraft makes this strategy possible. Modern planes are studded with environmental sensors that record flight conditions, while other sensors constantly assess the health of the airplane's subsystems. This information is fed to a central computer, forming a network that resembles the neural system of a primitive organism. At the end of each flight, maintenance crews can easily download the data for analysis. Airlines have been using this information to improve their safety performance since the early '90s, but two years ago the FAA began collecting these records as part of its Aviation Safety Information Analysis and Sharing (ASIAS) system.

This year, the FAA opened the Accident Investigation and Prevention Service to scrutinize the ASIAS data. "We're having many fewer accidents, but the ones we do have are being caused by threats that are much harder to detect," says Jay Pardee, the director of the new office. As an example of the kind of problem that ASIAS data could prevent, consider Comair Flight 5191, which was scheduled to take off from Lexington, Ky., in August 2006. Thinking they were on 7000-foot Runway 22, the pilots failed to get their aircraft airborne before they ran out of asphalt on the runway they were actually on—3500-foot Runway 26. The airplane's wheels clipped an airport perimeter fence and the plane plowed into a grove of trees 1800 feet from the end of the runway. All 47 passengers and two of three crew members were killed. After the accident, the FAA reviewed 25 years of data and discovered that 80 commercial aircraft around the country had either taken off or tried to take off from incorrect runways. "Nobody connected the dots," Pardee says.

Following the AF 447 disappearance, other Airbus 330 operators studied their internal flight records to seek patterns. Delta, analyzing the data of Northwest Airlines flights that occurred before the two companies merged, found a dozen incidents in which at least one of an A330's airspeed indicators—4-inch-long, pressure-sensing pitot tubes located on the fuselage under the cockpit—had briefly stopped working. Each time, the flights had been traveling through the Intertropical Convergence Zone, the same location where Air France 447 disappeared.

In the case of the Northwest A330s, the pitot tube malfunctions had been brief and harmless. But what if a severe version of the problem had struck Air France 447 amid more unforgiving circumstances?

We're having many fewer accidents, but the ones we do have are being caused by threats that are much harder to detect," says Jay Pardee, the director of the FAA's new Accident Investigation and Prevention Service.

BUILDING A SAFER AIRFRAME

From the way the floor of the crew's rest compartment had buckled, French investigators determined that the fuselage hit the water more or less intact, belly first, at a high rate of vertical speed.

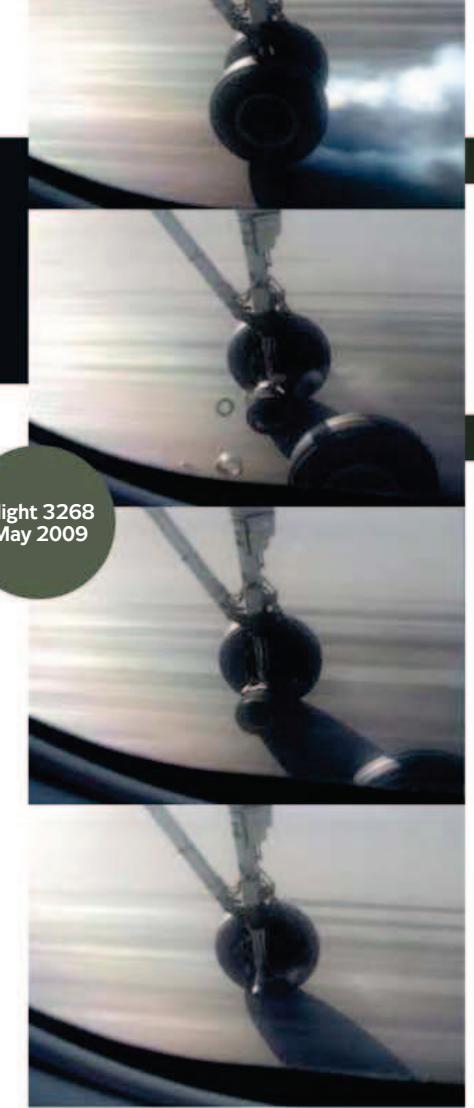
AT LAST, ON JUNE 6, THE MULTINATIONAL SEARCH effort began to find evidence of the crash. The Brazilian military recovered bodies and debris floating approximately 40 miles north of the last automatic Aircraft Communications transmission. Over the next two weeks, search vessels retrieved 51 corpses from a stretch of ocean 150 miles wide, along with bits of wreckage—a section of the radome, a toilet compartment, part of a galley—that collectively added up to less than 5 percent of the aircraft. The largest single piece was the tail fin, marked with the distinctive blue and red stripes of the French national carrier.

The most important piece of the wreckage, however, remained missing. More than a month after the plane went down, despite the joint efforts of the French and U.S. navies, the black box still hadn't been found. Given the huge search area, the ruggedness of the undersea terrain and the depth of the water (up to 15,000 feet), locating the recorder, let alone retrieving it, was proving to be an enormous task. Once the unit's acoustic pinger passed its 30-day certified life span, the chances of recovering the black box became virtually nil.

Without the box's data, the only physical evidence of the airplane available to investigators was the mangled wreckage. From the way it had been deformed—in particular, the way the floor of the crew's rest compartment had buckled upward—French investigators determined that the fuselage hit the water more or less intact, belly first, at a high rate of vertical speed. Added to the ACARS messages and the satellite weather data, the evidence began to conform to a possible scenario.

By 10:45 pm, 10 minutes after the last radio transmission, the plane hit the first, small storm cell in the Intertropical Convergence Zone. Fifteen minutes later, it hit a larger, fast-growing system. And then, just before its last ACARS transmissions, the plane hit a whopper, a multicell storm whose roiling thermal energy rose more than 3 miles higher than AF 447's altitude. Buffeted by turbulence, near the heart of a strong thunderstorm, the pitot tubes froze over. Lacking reliable speed indicators, the airplane's computerized Flight Management System automatically disengaged the autopilot, forcing the co-pilots to fly the airplane manually.

Without autopilot, the pilots had no envelope protection restrictions, which are designed to keep the pilot from making control inputs that could overstress the aircraft. This is particularly dangerous for airliners at high altitudes. The thin air demands that airplanes fly faster to achieve lift, but they still must remain below speed limits. Flying too fast can create a phenomenon known as mach tuck, when supersonic shock waves along the wings shift the aircraft's center of pressure aft



Flight 3268
May 2009

and can make it pitch into an uncontrollable nose-dive. Flying too slow can cause a plane to stall.

AF 447's flight crew, disoriented in the storm, uncertain about their speed and buffeted by turbulence, could easily have taken the A330 outside its flight envelope. "The fact that they didn't transmit a mayday would seem to indicate that whatever happened to them happened quickly," says William Waldock, a professor of safety science at Embry-Riddle Aeronautical University in Arizona.

WITHOUT MORE DATA, THIS KIND of scenario can never be verified completely. But the global aviation community has already taken steps to prevent another accident like AF 447. Within days, Air France replaced pitot tubes on its Airbus planes with ones made by another company, and in July Airbus

PASSENGERS USUALLY FEEL RELIEF when their plane touches down. But those peering out the windows of Colgan 3268 this May were horrified to see a wheel rolling away from their airplane during an otherwise routine landing. The end of an axle in a wheel bearing snapped as the Q400 Bombardier screeched across the runway—and as a passenger shot a cellphone video (left) of the chilling event. The airplane safely landed on its remaining tires.

Investigators found that the wheel bearing failed after it overheated during the landing. Wheel bearings are just a few of thousands of parts that endure the stress of repeated takeoffs, flights and landings. Maintainers and designers constantly adopt new materials and inspection devices to prevent heavily stressed parts of planes from failing during flights.

1. Wheel Bearings

Wheel bearings support the entire weight of the aircraft on a surface area of a few square inches, and during a landing they accelerate from 0 to 2000 rpm in less than 1 second. Ball bearings made from new ceramic formulas can better resist the temperature changes and physical stresses of these conditions.

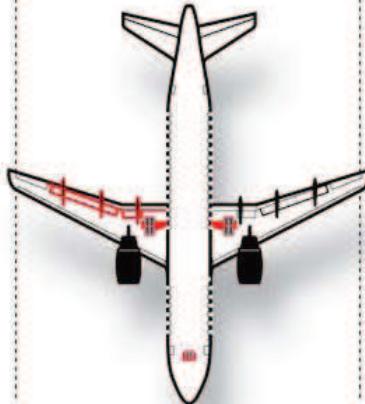
2. Wing Spars

Stress on the wing is borne by the spars. Boeing's 787 Dreamliner is the first civilian airplane to use carbon composites to form spars, but designers added extra metal fasteners to stiffen the wings after tests showed they couldn't handle the FAA's maximum aerodynamic load limits. As with other composite parts, crews use ultrasound to seek early signs of

failure. Resin-filled nano-structures embedded in the material could patch cracks as soon as they form.

3. Wing Skin

Wings endure high pressures while generating lift; stress on the wings' metal skin tends to

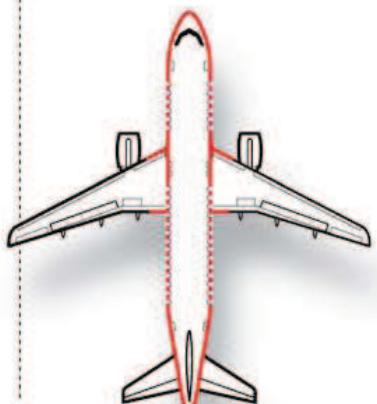


peak in areas where the wing connects to the fuselage. Wing skin is installed in panels held together with fasteners. Every hole or deformation that interrupts the skin makes it more susceptible to cracking, so maintenance crews inspect areas around the fasteners with ultrasound equipment for signs of weakness. Researchers at Sandia National Laboratories are designing paper-thin pressure sensors that continually monitor for cracks.

4. Fuselage Skin

Aluminum fuselages are built to handle changes caused by cabin pressurization—which inflates and deflates the body of an airliner as much as a quarter of an inch—but tension stress still spreads across the entire fuselage. Windows, doors and rivet holes magnify

this stress. Engineers understand metal fatigue, but new materials like carbon composites pose unique safety issues. Maintenance workers use ultrasound and other non-invasive scanners to find deformations and fractures inside composite materials.



advised other airlines to do the same. Three months later the FAA turned the recommendation into a regulation.

To be sure, the pitot tubes are not the definitive cause of the crash. Even if they had failed, that alone should not have been enough to bring down an airliner. As in virtually every fatal air crash, what doomed AF 447 was not a single malfunction or error of judgment, but rather a sequence of missteps that crash investigators call the accident chain. "There's always a series of events," the FAA's Pardee says. "That means there are multiple opportunities to intervene and break that accident chain."

In the case of AF 447, the error chain included the co-pilots' decision to fly too close to severe thunderstorms—bad weather that several other pilots, flying similar routes that night, had chosen to give a wide berth. There were certainly other links in the accident chain that pushed AF 447 beyond its limits. But unless the black box is found, we may

never identify those links. And that means safety officials might never learn the full lessons of the disaster. To prevent a similar loss of forensic evidence, executives at Airbus say they are now studying alternatives to physical black boxes. It is feasible to create a system that could broadcast not only text messages like ACARS but comprehensive data about the status of every aircraft, in real time. The aircraft would continuously transmit data to VHF stations within a radius of 125 miles, or by satellite if the plane is farther away.

Airliners in flight could one day stream all sorts of high-speed data, sharing information directly with one another. "It would be a network in the sky," says Bob Smith, chief technology officer at Honeywell, which manufactured AF 447's ACARS. "Aircraft could pass not only information about their location and where they're headed," he says, "but whole data sets. An airliner over Seattle could send its weather radar picture to a plane inbound from Dallas. And the guy from Dallas could pass it along to five other aircraft." Military aircraft already use a similar system; it is not clear if civil aviation will adopt it.

The disquieting truth is that we don't really know precisely what happened to Air France 447, and perhaps never will. The same links in the accident chain could someday take down another unlucky airliner. If they do, improved technology might provide investigators with the data they need to make sure that the next time is the last time.



By Seth Porges

photograph by gregor halenda

SO YOU WANT TO BUY A

Netbook

The netbook formula is simple: Take one ordinary notebook, strip out some of its processing power, shrink its size by a little and reduce the price tag by a lot. And while early models lacked the ability to handle anything much more demanding than a Web page or a text document, new netbooks cram performance once reserved for full-size laptops into 2-pound packages costing around \$250 to \$500. These machines aren't designed to serve as your primary PC, but they are ideal as low-cost, low-mass secondary systems for carrying on a plane or around the house.

● A. Operating System

Microsoft's 8-year-old Windows XP has found a second wind powering low-cost netbooks, and the new Windows 7 was designed with netbooks in mind. Just avoid Windows Vista if you can—the bloated OS can overwhelm netbooks' low-power processors. Open-source devotees may also opt for a Linux netbook, although these are becoming less common. And sorry, Apple fans: no Mac netbooks just yet.



● B. Keyboard

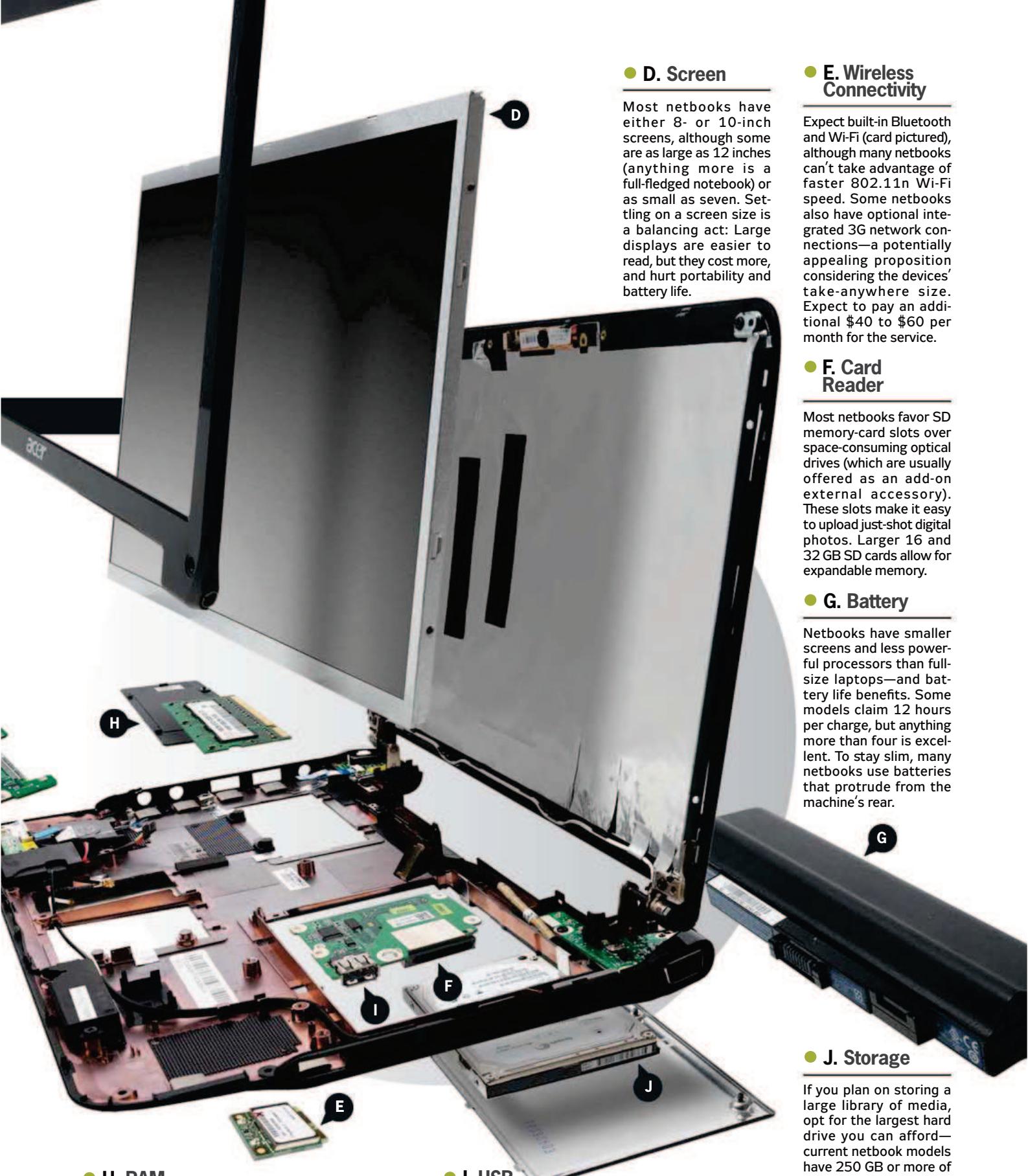
Although some newer models cram in full-size keyboards, the small size of most netbooks necessitates a shrunken typing space—usually 10 to 20 percent smaller—which can cause discomfort for people used to larger layouts. Be sure to test out any keyboard before you buy to make sure you find it comfortable.

● C. Central Processing Unit

The most common netbook configurations currently involve 1.3- and 1.6-GHz versions of Intel's power-efficient Atom processor. This is plenty of power for the simple applications netbooks are designed for, but future models will see faster speeds. And competitors such as Nvidia now offer netbook-targeted chipsets that aim to offer superior graphical performance. Most users should avoid anything slower than 1 GHz.

What about those subsidized netbooks?

Most of the major wireless carriers now sell dirt-cheap subsidized netbooks (they typically go for about \$200, though we've seen them sell for basically nothing during promotions). The catch: The machines come with long-term contracts for expensive mobile data plans—typically \$40 to \$60 per month, on top of your other phone and Internet bills. Meaning that an almost-free netbook can suddenly cost an extra \$1400 over a two-year contract. Our advice: If you want take-anywhere 3G network access, stick to a separate 3G modem. The monthly fees will be the same, and it won't be tied to one computer.



● H. RAM

The more random-access memory (RAM) a netbook has, the better it will be able to handle heavy-duty applications. Top-shelf netbooks currently come with up to 2 GB of DDR2 SDRAM, but 1 GB is enough for most applications (it's also the minimum amount of RAM required to run Windows 7).

● I. USB

Netbooks usually have fewer USB ports than full-size notebooks—typically one to three. One useful feature to look out for: Some models allow users to charge other gadgets through a USB port, even while the netbook is in sleep mode—so you can charge a phone or MP3 player while the computer is stashed in a bag.

● D. Screen

Most netbooks have either 8- or 10-inch screens, although some are as large as 12 inches (anything more is a full-fledged notebook) or as small as seven. Settling on a screen size is a balancing act: Large displays are easier to read, but they cost more, and hurt portability and battery life.

● E. Wireless Connectivity

Expect built-in Bluetooth and Wi-Fi (card pictured), although many netbooks can't take advantage of faster 802.11n Wi-Fi speed. Some netbooks also have optional integrated 3G network connections—a potentially appealing proposition considering the devices' take-anywhere size. Expect to pay an additional \$40 to \$60 per month for the service.

● F. Card Reader

Most netbooks favor SD memory-card slots over space-consuming optical drives (which are usually offered as an add-on external accessory). These slots make it easy to upload just-shot digital photos. Larger 16 and 32 GB SD cards allow for expandable memory.

● G. Battery

Netbooks have smaller screens and less powerful processors than full-size laptops—and battery life benefits. Some models claim 12 hours per charge, but anything more than four is excellent. To stay slim, many netbooks use batteries that protrude from the machine's rear.

● J. Storage

If you plan on storing a large library of media, opt for the largest hard drive you can afford—current netbook models have 250 GB or more of storage. But if you just want a netbook for surfing the Web and writing documents, solid-state drives, which hold less data but are more durable and potentially faster, may be preferable. **PM**

R U N

S I L E N T,

HUMANS HAVE LONG EXPLORED THE OCEAN AT A DIRIGIBLE'S PACE.
GRAHAM HAWKES PLANS TO CHANGE THAT WITH A SUB THAT FLIES.

DEEPFLIGHT

RUN

Ten in the morning is a late start for the Super Falcon. For the past two days I've strolled down to the pier at dawn, just as the fog begins to roll off Monterey Bay, to watch as crewmen peel back a collapsible garage to reveal the winged submersible and prepare it for the water. But the Super Falcon's rigorous workout has finally caught up with it. On their first dive, Graham Hawkes, the sub's designer, and pilot trainee Lee Behel inadvertently tested its ability to navigate kelp beds. The vessel had to be cut free of the stalks by a safety diver. Then, they pushed its limits with "upset" maneuvers—near vertical dives and 90-degree rolls—that resulted in a busted prop and broken rudder. "The whole idea was to find any weak points, and we did," Hawkes said as he replaced plastic rudder fittings with stronger metal components. "This was a good thing."

Still, it meant that Hawkes had to drive 250 miles round-trip from Monterey, Calif., to his

SLEEP

BY MARK SCHROPE PHOTOGRAPH BY CHUCK DAVIS

The Super Falcon submersible uses its inverted wings to move through water like a plane through air.

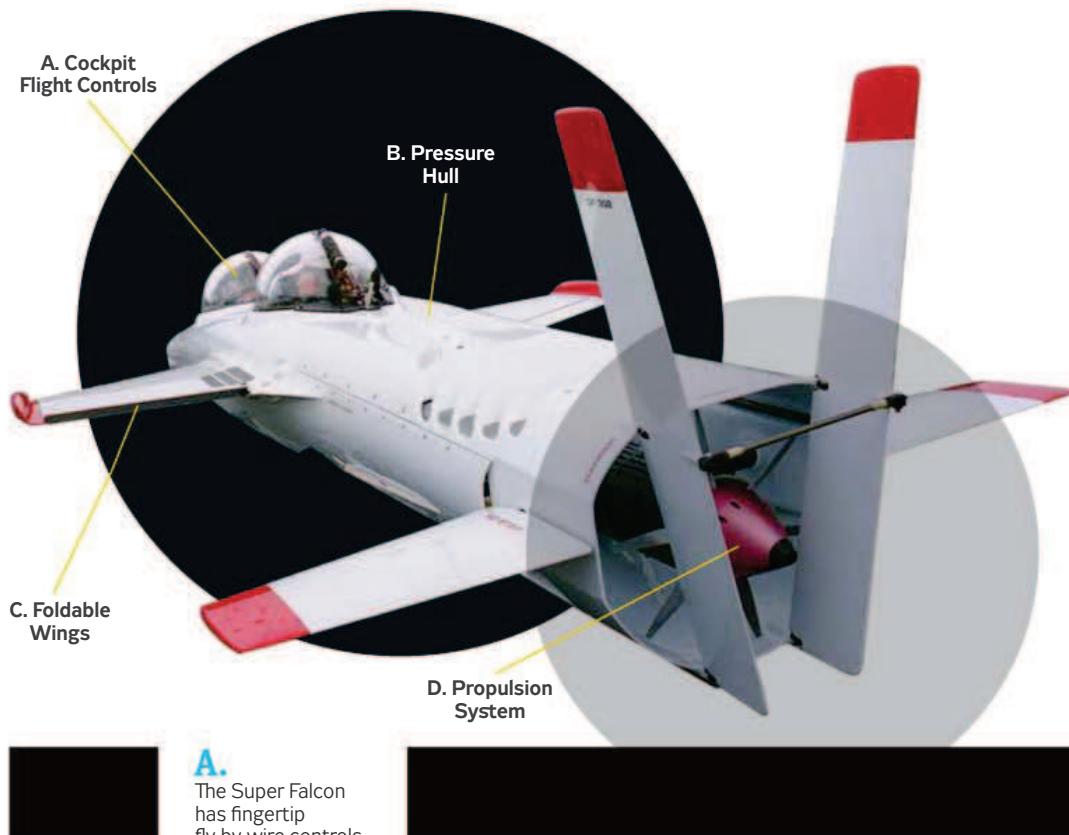
workshop north of San Francisco to get new prop blades—an errand that took until 3 am. But because today's my day to get behind the controls, I'm all for getting the submersible in top working order.

Like Behel, I'm here at the Coast Guard pier in Monterey for flight school—a training course for prospective Super Falcon pilots. Behel has a bit more flight experience than me, however: He used to fly F-4 Phantom jet fighters for the military. It's not surprising that he was drawn to the Super Falcon, since the two craft share many of the same design principles. Long and thin, with a tapered nose, the Super Falcon has rear horizontal stabilizers, two large tail rudders and dual acrylic cockpit canopies. It also has inverted wings, which turn the aeronautic concept of lift upside down, allowing the sub to literally fly through the water. Whereas conventional subs rely on ballast, the Super Falcon descends as forward speed creates a pressure differential between the top and bottom of the wings. Free of ballast, the sub is positively buoyant, which dramatically increases safety. Lose power and the vessel automatically floats to the surface.

Once the Super Falcon has been repaired, the crew hitches a custom-built trailer to the back of a Toyota Land Cruiser and I climb into the sub's rear cockpit. Hawkes goes over the controls and life-support systems with me, then climbs into the front. As the acrylic canopies descend over our heads, the world outside goes eerily silent. All I hear is the intercom chatter between Hawkes and dive supervisor Dirk Rosen. Then, a slight jolt. The SUV shifts into reverse and slowly backs us into the water.

CHALLENGER DEEP

Graham Hawkes is to ocean exploration what Burt Rutan is to private space travel—a relentless innovator who challenges the accepted wisdom in his field by inventing around it. He began his career in the 1960s as a civilian ocean engineer, working on underwater vehicles for the British Special Forces. For the next two decades, he designed submersibles for the oil industry and for scientific research. Some of those vessels found their way into movies. Hawkes piloted one, the Mantis, in the 1981 film *For Your Eyes Only*—right into the side of James Bond's rig (at the director's insis-



A. The Super Falcon has fingertip fly-by-wire controls for pitch, roll and yaw. A digital heads-up display combines navigation and vital dive data.

B. Conventional subs require circular or spherical hulls to withstand water pressure. The Super Falcon uses a custom isotropic glass-resin matrix composite that can be shaped to accommodate the human body.

C. A set of inverted wings allows the sub to "fly" through the water and dive without ballast. When on land, the wings can fold up for easy transport.

D. Powered by 24 4-volt lithium-phosphate batteries, the 7-hp electric motor is mated to a 24-inch-diameter prop that generates 508 pounds of thrust.

tence). Two of his bubble-hulled Deep Rover subs were used by James Cameron for his *Aliens of the Deep* documentary.

But after launching the first Deep Rover, Hawkes had a nagging feeling. "I remember sitting on a rock in Halifax Harbor thinking, we can do better than this," he says. While aviation advanced swiftly and consistently over the past century—yielding highly maneuverable craft that can fly faster than the speed of sound—progress on undersea vehicles had been slow. As a result, submersibles still worked like the aquatic equivalent of hot air balloons, creeping around the oceans at the pace of a jellyfish.

Hawkes wanted to explore the concept of moving more efficiently through the ocean and create a sub that would grant unprecedented access to everyone from tourists and legislators to marine biologists. Soaring underwater, he decided, would take wings, and so he founded Hawkes Ocean Technologies (HOT), a skunkworks dedicated to building the Deep Flight family of winged submersibles. The prototypes began to take shape at HOT's research facility, based at a marina in Richmond, Calif.

The Super Falcon, the fourth in the series, has its roots in one of the most ambitious undersea exploratory missions in modern history. In 2005, Hawkes teamed up with adventurer Steve Fossett to create a sub that could be piloted to the deepest part of the ocean—a spot in the Pacific named Challenger Deep, 36,201 feet below the surface. Fossett agreed to fund the sub, named Deep Flight Challenger, in hopes of setting the world record for a solo dive. But two years into the project, he plummeted from the

sky over Nevada in his single-engine Bellanca Super Decathlon. Ownership of the Challenger passed to Fossett's estate when he died. But the technology developed for the Challenger still belonged to HOT.

As it happened, Hawkes got the opportunity to use that technology twice more: He was midway through constructing his own Super Falcon when venture capitalist Tom Perkins contracted him to build a submersible that could operate from his *Maltese Falcon*, one of the largest sailing yachts in the world. One Super Falcon was delivered to Perkins in November 2008; the other Hawkes finished and kept. The subs diverged from the Challenger in two significant ways: They carried two people upright, as opposed to one prone. And to avoid the extreme cost of building a hull to handle great depth, the team used a much cheaper and easier-to-fabricate composite of their own design, called Sea Glass 11. The Super Falcon is rated to a depth of 1000 feet, but future iterations can be designed to go as deep as desired, and plans for such subs are already under way.

TEST FLIGHT

The inside of the Super Falcon is tight, but comfortable enough. Seating is recumbent, and my legs straddle a carbon-dioxide scrubber that, along with an oxygen control at my right shoulder, keeps air in the pressurized hull breathable. Each of the two in-line piloting positions has a full set of controls—the throttle is to the left, and on the right is a finger-tip fly-by-wire joystick—but Hawkes, in the front position, has the master controls. Our eyes are just level with the chop as we cruise away from the launch; then Hawkes takes us down and we are enveloped by murky green water. Away from the waves and weekend boaters, the underwater atmosphere is peaceful, and for a moment it feels as if we are floating motionless.

Hawkes coaches me on how to read the heads-up display—which has an artificial horizon similar to an airplane's instrument panel—then gives me control. Piloting the sub by joystick is as intuitive as a video game, but orienting myself in the watery gloom is difficult and Hawkes warns me that I'm listing to the right. I correct the trim, then glide us gently back to the surface, where Hawkes takes the controls and puts my gentle wobbling in the water into perspective. He takes us down abruptly, descending so steeply it's disconcerting. The water around us goes quickly from blue to dark green and, finally, to brown as we reach 50 feet.

200
feet per minute dive
400
feet per minute ascent
508
pounds of thrust
1.5
million dollars



Graham Hawkes at Hawkes Ocean Technologies workshop in Richmond, Calif. The Super Falcon is the first production-ready winged submersible.



We could, in theory, be down here awhile. The Super Falcon has a 29-mile range and can run 5 hours between battery charges. Its top speed is 12 mph—not fast by land-speed standards, but positively sports-car-like for submersibles. It can glide and bank like a dolphin, even, Hawkes suspects, perform barrel rolls—though I was sadly not the guinea pig for that maneuver.

The Super Falcon's ability to move like marine animals—and keep up with them—makes it valuable for everything from ecotourism to scientific research. "Nobody has had a sub that can go that fast," says John McCosker, chair of aquatic biology at the California Academy of Sciences. McCosker would like to use the Super Falcon to follow white sharks. "It could help us get a better understanding of how they track prey prior to attack," he says. "Plus, there may be behaviors we don't even know about that we could only see by hanging out with these animals."

But getting the Super Falcon close to sea creatures is more than a matter of speed. Hawkes worked to minimize the sub's electrical field—sharks, for instance, have electroreceptors that can detect even minute disturbances—and make it hum along as quietly as possible. He also kept lighting to a minimum. The bright lights used on conventional subs, while necessary for some jobs, can scare away

marine life. "If weapons-grade emissions are coming from the lights," Hawkes says, "you're only going to see the stuff that's deaf, dumb and blind."

Eventually, the team hopes to add a range of advanced technologies to the Super Falcon—sonar to detect obstacles, hydrophones to hear animals or boats before surfacing, and low-light cameras. The Super Falcon's wings are already fitted with lasers that can alert the pilot to obstructions a hundred feet or more ahead. Future subs may also have additional thrusters for hovering, as well as a robotic arm to collect scientific samples.

In the dark water, I try toggling on the Super Falcon's lasers, but Hawkes tells me the sub's batteries are too low. "Turn that switch off and hang on—we're coming straight up," he says, and we shoot toward the surface. We breach suddenly, popping a third of the sub out of the water. As I catch my breath, I hear Rosen over the radio. He's concerned that sailboats are coming into the area and wants to tow the Falcon back to the launch. Hawkes tells him to hold off. "We're doing one more," he says, and no one argues. After all, it's his vehicle. **PM**

Larger St Smaller F

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The Guerrilla Mechanic

By Mike Allen

20

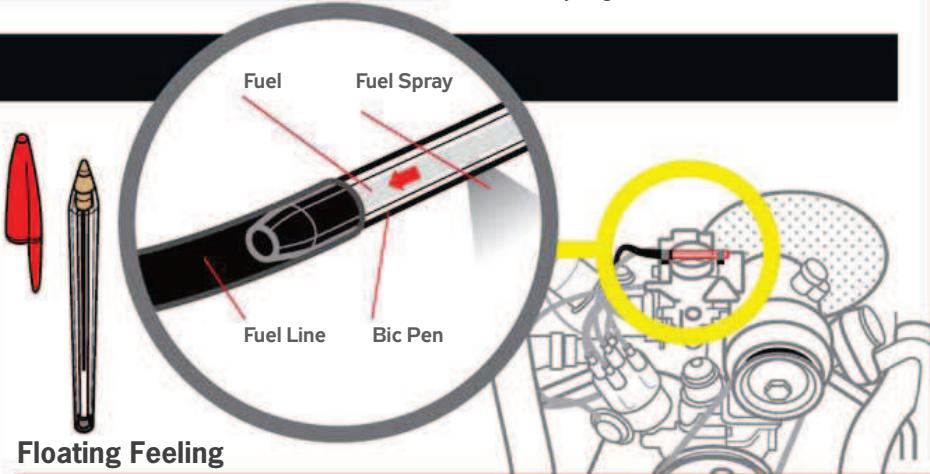


OUTSIDE-THE-TOOL-BOX TIPS FOR GONZO REPAIRS

Illustrations by Dogo

Charge Attack

Deeply discharged car batteries can take days to charge with a conventional charger, because their internal resistance is high. Myth-Buster (and PM contributing editor) Jamie Hyneman suggests using a DC stick welder for a few minutes to wake the battery up. Use the lowest amp setting, stand back, and, if the battery starts to get hot, cease immediately.



Floating Feeling

Disintegrated float in the carburetor of your dune buggy? Make a fuel injector out of a Bic ballpoint. Gut the pen, leaving the plug in the top. Disconnect the fuel line from the carb, and push it over the Bic's pointy end. Strap the pen—vent hole facing down—over the carb throat with a rubber band or a piece of wire. The gas squirts out the vent hole. The engine will run pretty well at half throttle. It won't idle, and will run lean at full throttle, but at least you'll be able to drive back to civilization.

Stuck Wheelo

Kicked and hammered the wheel of your car, but it still won't pop off the hub? Run the lugs back on and leave them two threads shy of tight, then lower your ride to the ground. Drive the car around the block while you simultaneously stab the brakes and shake the steering wheel. The wheel and tire assembly will pop loose. Next, wire-brush the hub/wheel mating surface to clean up any corrosion; use antiseize compound to prevent a recurrence.



Clean the Clipper

Free your lawnmower deck of dried grass by idling it for 5 minutes or so while spraying water under the blade. No more putty-knife scraping.

Liquor Fix

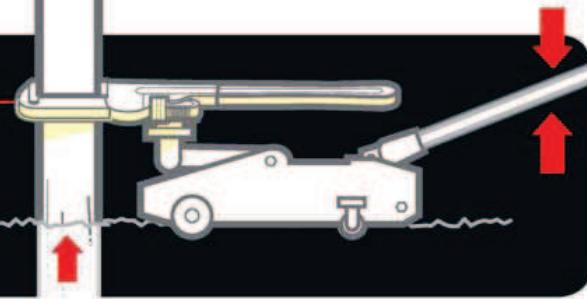
Some of us save money by using water for windshield-washer fluid. Naturally, the water should be replaced with a premixed winter blend when cold weather rolls around. But who thinks of everything? Here's the scenario: The water freezes. You can't find the blue fluid. Instead of waiting for spring, you remember that cheap vodka works fine. You don't have any vodka, Vladimir? Try methyl or isopropyl alcohol, which can be found at most hardware stores. Even rubbing alcohol will do in a pinch.

Not Just a Digger

Demolishing a room for a home improvement project is a lot easier with a tool commonly found in the shed: a square-nose shovel. It removes just about anything that a thin blade can get under. The handle provides plenty of leverage to pull up carpeting, tacks and all. If the blade is even a little bit sharp, old vinyl floor tile or linoleum lifts from the adhesive. Peel old quarter-round, wainscoting and crown molding off the walls and ceiling. Even crumbly old roof shingles—nails and all—peel up easily. Drywall doesn't have a chance. Best yet, you've already got a shovel handy for cleaning up after the demo is done.

Mechanical Advantage

Got a bunch of fenceposts to remove? You can dig 'em up with a shovel, huff, puff. Better yet, get a big pipe wrench and clamp it to the base of the post about 8 inches above the ground. Now use a floor jack or just a scissors jack under the head of the wrench to lift the posts—even if they're anchored in concrete.



Rules of Thumb

Need a shim?



The thicknesses of some common items:

- Post-it note 0.004 inches
- Credit card 0.030 inches

Lost the feeler gauge?

- Beverage-can lid 0.014 inches (typical ignition-point gap)
- Jumbo paper clip 0.040 inches

No scale handy?

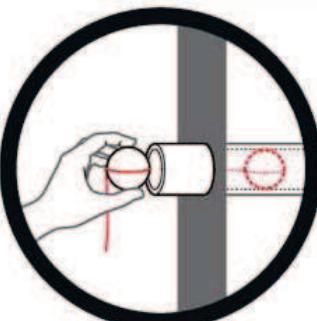
- 1 gallon of water 8.4 pounds
- 1 gallon of gas 6.2 pounds
- 1 gallon of diesel 7.2 pounds

No ruler?

- Quarter 0.955 inches in diameter
- Credit card $3\frac{1}{8} \times 2\frac{1}{8}$ inches
- 1-inch box wrench roughly 12 inches long

Can't find the measuring cup?

- 12-ounce soda can 1.5 cups
- Oil container cap holds about an ounce
- Spray-paint cap 4.5 ounces



Baker's Secret

Have you ever struggled to fill a transmission on a transfer case or other hard-to-reach reservoir? Since space is so tight, funnels are useless. Try this: Fill a quart zip-lock freezer bag with lube, and cut a quarter-inch off one corner.

You've just made the automotive equivalent of a pastry bag, used for decorating cakes. Now you can squeeze lube up or over into the fill hole from almost any angle.

5 Uses for: AEROSOL CARB CLEANER

Cleanup in Bay 4

It's not just for cleaning carburetors anymore. It makes a perfect solvent for most anything around the shop. Spray some on a sticky gasket or on gasket sealer residue to make scraping a lot easier.

Mounting Issues

Trying to mount a tubeless tire but can't quite get the bead to seat so you can inflate it? A 2-second shot of carb cleaner, followed by a flick of your lighter, literally blows the beads onto the rim, allowing you to air up normally. Warning: We're not responsible for singed eyebrows or pinched fingers.

The Running of the Wires

There are times when a length of conduit outstretches the fish tape. Then what? Tie some monofilament fishing line around a small sponge ball or a wadded-up plastic bag, then stuff it into one end of the conduit. Attach a Shop-Vac to the other end and flick the switch. Within seconds, the sponge or bag is drawn through the conduit and into the vacuum. Now use the fishing line to pull the wires.

Coming Unglued

Got some leftover gooey adhesive from that Grateful Dead sticker on your new used minivan? Carb cleaner dissolves it and won't damage the paint, unless your car is coated with old-fashioned lacquer instead of modern enamel.

That Sucking Sensation

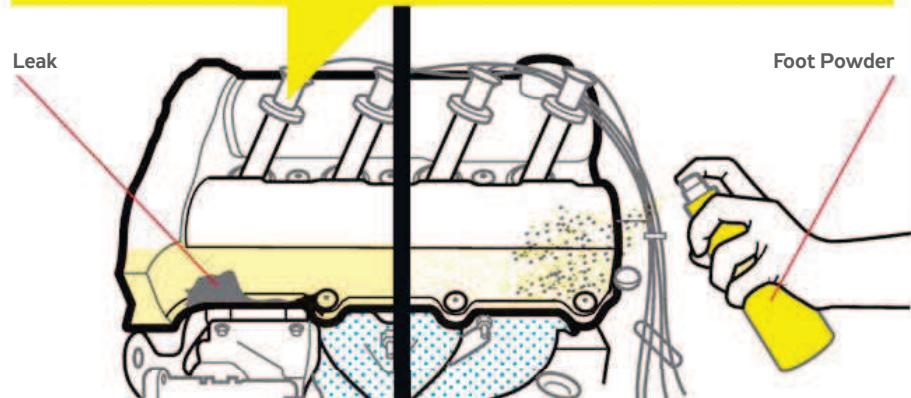
Is a vacuum leak somewhere under-hood causing that idle misfire? Use carb cleaner to find it: Spray a quick shot around the intake manifold. As the cleaner is sucked into the leak, the lean mixture is enriched, momentarily raising the idle speed. Short puffs narrow the search.

Get Me Outta Here

Door locks gummed up by years of pocket lint, especially if someone's been lubing with 3-In-One oil (which traps dirt)? Blast carb cleaner into the key slot to remove the glop, then lube with nonsticky graphite.

Dusting for Oil Leaks

Matt Crawford, author of *Shop Class as Soulcraft*, came up with this: "Chase oil leaks by cleaning the engine, and spraying a generous coating of foot powder in the area of the leak. Run the engine for a minute or two, and any fresh oil will soak into the white powder, leaving a noticeable stain."







The New Wildcatters

Texans' oil-boom attitude could put the state in a surprising position—leading the charge to alternative energy.

By Jennifer Bogo



Photographs by Jason Fulford

Driving along Broadway in Sweetwater, Texas, one could justifiably assume the city is on its way down, not its way up. Cobwebs crowd the windows of abandoned storefronts, and peeling signs hang from cracked facades. It is only after I pull up to the mayor's office, pausing to study the street more carefully, that I notice a real clue to the city's changing fortunes: The blond stone building is neatly sandwiched between Craig A. Johnson, Independent Petroleum Landman, and Evans Enterprises, "Your source for wind turbine maintenance solutions."

Greg Wortham, the mayor of Sweetwater, is a compact man who, contrary to his West Texas roots, speaks quickly and easily, offering more information than is asked. As we

Dan Templeton stands on the nacelle of a 2-megawatt DeWind turbine in Sweetwater, Texas. Four of the world's five biggest wind projects are in Sweetwater's Nolan County.

leave downtown in his silver Ford Escape Hybrid, he points to one low-slung building after another. "That's a British company, Altezza. They work on the outside of the blades and towers, like spacewalkers. That building had been vacant for a dozen years, easily. This is General Electric—there's 150 workers there. It used to be a Coca-Cola storage facility. At one point, a quarter of all GE turbines in the world were built here. Northwind moved into that one; it held a company that made deer blinds."

Along the narrow state road, warehouses evolve into wide-open plains where Black Angus cattle meander among the bases of sleek white turbines. I have to crane my neck in order to take them in. When the blades revolve to 12 o'clock, the turbines stretch to a height twice that of the Statue of Liberty and sport a wingspan greater than a 747's. As I peer out the window, Wortham identifies turbine models the way a bird-watcher ticks off species: The nacelles of Mitsubishi's appear to have two eyes and a mouth on the back, he tells me. Siemens have a tail fin and are long and sleek like a bullet; General Electrics are shaped like a breadbox and Vestas turbines are cut across the bias with a clean diagonal line.

The irony of this scenario in a state better known for its drilling rigs is not lost on Wortham. "If you picked 50

states, plus D.C., and asked anybody in the U.S. to rank all 51 [for wind power], Texas would be somewhere around Mississippi," he says, "at the bottom."

ince the Spindletop gusher inspired the first wave of wildcatters in 1901, Texas has had a history of going all out in the energy business—but not in ways that are necessarily friendly to the environment.

If Texas were a country—and Texans love to remind you that it once was a sovereign republic—it would rank seventh in carbon-dioxide emissions: Its economy accounts for more than a quarter of total U.S. natural gas production and oil refinery capacity, and its residents consume up to three times as much energy as residents of neighboring states.

If it were a country, Texas would also rank sixth in wind power, after Germany, the U.S. as a whole, Spain, India and China. While U.S. wind-power capacity grew by 43 percent in 2007, in Texas it rose by 57 percent. All told, the state's

turbines now produce more than 8300 megawatts of electricity, enough to power about 2 million homes; nearly 3000 are produced in Sweetwater's Nolan County alone. In comparison, Vermont produces 6 megawatts; Oregon, 1408. Even California generates just 2781 megawatts from wind power, and it built its first wind project nearly three decades ago.

And that is the curious paradox of Texas: While seemingly more virtuous states labor over environmental impact assessments, Texans see a business opportunity and grab it—and so could very well end up leading the nation in clean energy. "In Texas, because we don't care about the environment, we're actually able to do things that are good for the environment," says Michael Webber, assistant professor of mechanical engineering at the University of Texas at Austin. "It's the most ironic, preposterous situation. If you want to build a wind farm, you just build it."

On private land, wind developers simply make a deal with landowners and pay them a royalty. But there's no siting review process for wind farms on state lands, either. Plus, the state's boundary extends 10.3 miles from the coast, a stipulation made by Sam Houston, Texas's president, before the republic joined the United States in 1845. Federal waters off all other coastal states begin 3 miles offshore, which means wind projects beyond that point—such as Cape Wind, which was proposed for Nantucket Sound in Massachusetts in 2001—fall under the jurisdiction of the Minerals Management Service.

"If you'd like to build a wind farm off the coast of Texas, you only have to deal with the Texas General Land Office, and we're a very eager leaser," Jim Suydam, the office's press secretary, says. "My boss is a Texas Republican. He's an old Marine lieutenant colonel who carries a gun in his boot. But you'll find no bigger proponent of offshore wind power, because he sees it as a vital part of a diversified revenue stream for public education."

Offshore oil and gas production have contributed \$6 billion to the Texas Permanent School Fund since it was established in 1854—but that source of income won't rise forever, Suydam says. So this summer the Texas General Land Office signed two offshore wind leases with Houston-based Baryonyx; they were the state's sixth and seventh. When the company goes into production, the state will take a cut—and resell the power. "It's different than in California, where it's all about carbon emissions," Suydam says. "Here it's all about making money."

Wind and Cotton

"Because there are so many landowners here, nobody gets rich out of this deal," says Cliff Etheredge (left), whose son Scott farms cotton on land in Roscoe. "It's just a small, steady income. If you take care of it, it'll put your kids through college and help pay debts. It's certainly a stabilizing influence on the economy."





Carbon Recycling

The Sunrise Ridge Algae pilot plant takes advantage of a copious resource: carbon dioxide. The gas is siphoned from the top of a stack at the Hornsby Bend Wastewater Treatment Facility in Austin, then pulled through a series of demisters and compressors (below). The CO₂ percolates into reactors downslope where it feeds algae, later processed into biofuel.



with simple carabiners and to make the last few rungs of a narrow steel ladder feel interminably long. But just 10 feet higher, thermodynamics change. A strong, cool breeze blows steadily through the rope tethering me to the top of the hub, around the carbon-fiber blades that taper off into the blinding sun. I shade my eyes and look to the horizon: Neat rows of turbines spin steadily—an alternative energy crop thriving in America's petroleum heartland.

Dan Templeton pops his head and shoulders up through the hatch to triple-check that my harness is clipped in. As a wind technician, he has climbed hundreds of such towers; his rangy body can go from 0 to 300 feet in about 10 minutes. "This job has a certain romance to it because you're working at such heights—there's some perceived danger," says Templeton, who now runs a program to train future technicians at Texas State Technical College in Sweetwater. This fall, 250 students were enrolled. "It's really not that dangerous," he says, "but for your typical country boy who likes to work outside and with his hands, it's the perfect job."

This year in Nolan County, the wind industry directly employed more than 1300 people. Some, like Bryan Gregory Jr., a third-generation potash miner, answered an ad in the paper and learned skills on the job.

"Wind has taken very good care of me and my family," he says. "I started at the bottom and worked my way up." Now Gregory's doing the hiring as a project manager at Bluarc Management Group, a renewable energy asset management firm. "In wind, our guys are cross-functional," he says. "They do everything from IT networking to maintenance to electrical and mechanical troubleshooting to crane work." This year, wind also provided Nolan County with more than 800 construction jobs.

"Up until 2000, the only economic development for 10 or 15 years was prisons," Mayor Wortham told me. Wind power took off after Texas passed a renewable portfolio standard in 1999, mandating that utilities generate 2000 megawatts of renewable energy by 2009. Coupled with a federal renewable-energy-production tax credit, turbines suddenly began to look profitable to wind developers and to communities like Sweetwater. While driving me around, Wortham pointed out Highland High School—both the old part, built in the 1930s, and the new \$8 million facility that will soon replace it. Property taxes on wind energy have poured more than \$30 million into Nolan County's economy, and in 2005 the population finally stabilized after a decades-long decline.

Roughly 11,000 people live in Sweetwater, where rust-brown pump jacks have long supplemented ranching income. Eight miles due west on Interstate 20 sits the cotton capital of Roscoe. It has about 1300 residents and half as many wind turbines—when the fourth phase of the

Roscoe Wind Complex was completed this summer it became the largest wind project in the world. Initially, developers were reluctant to build turbines on farmland because it involved negotiating with so many landowners. So five years ago, retired cotton farmer Cliff Etheredge organized family and friends into one group, under one contract—then paid for his own anemometer tower and took the data to a developer's door.

"This is the first time most of these landowners ever had a chance at a steady income," says Etheredge, who has since started his own business as a wind developer. Because there's not enough rain to recharge groundwater for irrigation, agriculture is touch and go. "Until recently, wind was a tremendous negative because it robbed us of our moisture—the evaporation rate here is many times greater than our rainfall," he says. "Now we're able to sell the wind. And it's a real blessing to us."

he Sunrise Ridge Algae test

farm sits deep within the Hornsby Bend Wastewater Treatment Facility in Austin, past mountains of fresh, dark Dillo Dirt—a compost made from treated sewage sludge and yard clippings—and just downslope from a pair of hulking anaerobic digesters. It looks less like a startup company than a squatters' camp. Sheets of

black plastic, crisscrossed by PVC pipes and rubber tubing, cover the ground. Sara Norris, the 24-year-old supervising engineer, greets me at the plastic storage shed that serves as the lab. "As I mentioned," she says, "it's very low-tech."

Slim and suntanned, with hair swept back into a long brown ponytail, Norris leads me over to a row of flat, 100-square-meter bags called helioreactors. The algae inside soak up the sun, doubling in number every other day. "You can step on them," Norris tells me as she strides onto their surface in black work boots. "They're really hardy." I follow. It's only after warm water seeps through the permeable fabric and swirls around my exposed feet that I think about what's inside: a mixture of nonpotable wash water and a nitrate- and phosphate-rich fertilizer, processed from sewage sludge. The algae love it; so, apparently, do the flies buzzing around my ankles.

A rancid smell wafts from the direction of the digesters, where bacteria break down the wastewater, forming methane and carbon dioxide. The plant burns the gases off in a stack. "When you combust methane, it produces [even more] carbon dioxide, and we use that to feed our algae and modulate the pH in our bags," Norris says. After

a few days, the algae is harvested and settled in a tank, where it becomes a deep-green pesto-like paste. Then it's dehydrated—for now, in propane dryers rigged from old filing cabinets—and the resulting “algae crackers,” which look like sheets of nori, are loaded into a catalytic thermolysis unit off-site. A chemical conversion process turns the algae into crude bio-oil, which can be run through the existing energy infrastructure of refineries and pipelines.

“A really critical part of algae as a viable fuel or energy source is that you’re able to get things for free, like nutrients and carbon dioxide,” Norris says. Texas produces 676 million metric tons of CO₂ a year, so the opportunities to site algae plants are almost endless. Norris rattles off likely candidates: cement plants, oil refineries, even cattle feed-lots. “The stoichiometry,” or the math behind the chemistry, “suggests that for every ton of algae you produce you consume one and a half tons of carbon dioxide,” she says.

Algae operations can squeeze value from another copious Texas resource: brackish water. The dusty town of Pecos, in the southwestern corner of the state, used to be cotton country—but with only 9 inches of rainfall a year and saline aquifers, the surrounding fields have long since dried up. Today, saltwater algae swirls like pea soup in open raceways behind a Texas AgriLife Research Station run by Texas A&M University. “It’s a traditional agro-nomic society here, but algae’s a plant too,” Mike Foster, the station’s director, says. “If we can show the growers that this is going to work, they’ll be the first ones to try it.”

Several hurdles—some biological, some technological—still need to be cleared. At Pecos, for example, scientists are looking for an algae species that can withstand temperature swings ranging from blistering to freezing. Researchers at the University of Texas at Austin, meanwhile, are experimenting with more efficient ways to extract oil from algal cells. But the payoff has the potential to be huge: Conservatively, algae can produce between 2500 and 5000 gallons of fuel per acre per year; soy produces 50 and corn, 250. If successful, Texans will effectively leapfrog first-gen biofuels to those poised to turn a profit.

But the state’s real strength in the clean-energy economy might lie in its entrenched dirty one. The Energy Independence and Security Act of 2007 mandates that U.S. biofuel production reach 36 billion gallons a year in 2022; only 15 billion gallons can come from corn-based ethanol. But while cellulosic ethanol and algae companies have sprung up from Boston to California, few have made it past the pilot-plant stage of 10,000 or so gallons a year—let alone to the commercial phase of tens of millions. Texas, on the other hand, has more than 26 refineries already processing 7.4 million barrels of petroleum a day.

“The biggest thing people fail to understand about energy is the scale,” UT’s Webber says. “We understand scale. We have scale of resource and scale of industry. If you want biofuels that satisfy 10 percent of our nation’s fuel consumption, which is required with the Energy Independence and Security Act, how are you going to produce and move and blend them? Energy, in the end, is about steel in the ground.”



Algae to Biocrude

Sara Norris, a San Antonio native and mechanical engineer, supervises a pilot plant for Sunrise Ridge Algae, which grows algae in flat, white helioreactors containing wastewater. Converting the algae to fuel can help clean up both air and water pollution, she says. “Algae just made sense to me.”



In other words, biofuels may have to come through Texas one way or another. And oil companies—hedging their bets against future carbon regulation and declining production—have already begun to nudge open that door. BP, Shell and Chevron have all backed companies working on cellulosic ethanol and algae-based biofuels. This July, even the leviathan Exxon announced a \$600 million investment in Synthetic Genomics, a biotechnology company engineering algae to continuously produce oil.

“When you’re a small company and just trying things out, you’ve got to be as cheap as you can be,” Sunrise Ridge Algae’s CEO, Norman Whitton, says—even spiking helioreactors with Perrier for a quick fix of CO₂ when necessary. “We’re trying to pioneer technology,” he says, “but we know that in the long run, in order to be even remotely relevant, it’s going to take an awful lot of investment.”

Last year, the gross domestic product for Texas’s oil and gas industry was \$200 billion. “We’re the headquarters

of the energy industry of today," Texas state representative Mark Strama says. "That should be our biggest competitive advantage at being the headquarters of the energy industry of tomorrow." He adds: "California has Silicon Valley, billionaires who made their money in technology who see renewable energy as the next Internet—and those guys are putting their money where their mouths are. What would totally eclipse all of our competitors is if the fossil fuels industry would say, 'We're going there.'"

With nearly 12 percent of the world's silicon-processing capacity, Texas, as it happens, has a Silicon Valley of its own. Dallas-based Texas Instruments invented the integrated circuit in 1958, and central Texas has since grown into a world leader of semiconductor chip manufacturing. "As a result, you have thousands of people who know how to lay microcircuitry on glass, which is basically how chips are made," Steve Taylor, a senior manager of corporate affairs for Applied Materials, says. "And that's the same concept for solar."

The fastest growing market for chip-based products—cellphones, BlackBerrys, laptops and iPods—has moved to Asia, taking semiconductor manufacturers with it. But the talent pool that remains behind in Texas is, in effect, already partially trained to work in a solar factory. "We have a huge market for solar panels, and we have a lot of empty space to put the panels out there," Taylor says. "If Texas takes the initiative, it could be a center for not only solar-panel installation, both rooftop and utility scale, it could also create solar manufacturing jobs here."

Applied Materials makes equipment for manufacturing microchips in Austin and flat-panel displays elsewhere. Three years ago it used that expertise to begin making equipment for thin-film solar panels, which it sells to factories overseas. So far there's only one factory making solar panels in Texas, and it begins production this December. Austin-based HelioVolt uses a thin-film technology too, but with copper indium gallium selenide (CIGS) as the semiconductor instead of silicon. The company coats 2 x 4-foot sheets of glass with CIGS to form circuits, rather than discrete solar cells. These "photovoltaic integrated circuits" can be used for curtain walls, rooftops or ground-mounted solar installations.

Texas has already proven that it can deploy a large-scale renewable—wind. Soon, it will also have the transmission lines to handle power from solar as well. Texas is the only state besides Hawaii and Alaska to have a self-contained electrical grid—regulated by the Electric Reliability Council of Texas, not the Federal Energy Regulatory Commission—and the Public Utility Commission recently approved a \$5 billion expansion to the windiest areas of the state. (T. Boone Pickens has delayed his plan to build a

wind project in Pampa until these lines reach the panhandle.) Plus, solar could provide power during the day when electrical demand is highest and wind is at its weakest.

According to the National Renewable Energy Laboratory, by developing less than 1 percent of its total land area for solar, Texas could generate enough electricity (without energy storage) to satisfy the state's 2007 demand for more than 300 million megawatt-hours. So far, California leads the country with 528 megawatts of grid-tied solar, followed by New Jersey (70), Colorado (36) and Nevada (34). Less than 5 megawatts of solar power are grid-tied in Texas.

But the state's streamlined regulatory system could vault Texas to lead in solar power too. For example, this summer San Antonio's utility signed a contract with Tessera Solar for a 27-megawatt project in West Texas; the first units are expected to come online by the end of next year. That pace stands in stark contrast to Tessera's experience in California, where the company signed a contract for an 850-megawatt project in 2005 and only recently submitted the 5000-page impact assessment. While the scale of the two projects is vastly different, it is similar to another moment in the two states' history, such as when, in 1999, Texas's 30-megawatt Delaware Mountain Wind Farm began operations on a Culberson County ranch. Texas didn't build small wind projects for long.

The wind boom in Texas has been due, in part, to basic mechanics—turbines are a time-tested technology. Solar, by comparison, is still relatively immature. "The flip side is that the potential for solar to come down in cost is much greater than that of wind," B.J. Stanberry, HelioVolt's chief

strategy officer and founder, says. In fact, the price of solar panels has already dropped 40 percent since last year. "So what happens when you have a cost-effective business opportunity in Texas?" Stanberry asks. "Well, we move in and take over."

ext to the northbound lane of I-35 in Austin sprouts unusual landscaping: a row of 16-foot-high "sunflowers" with photovoltaic panels cupped like high-tech petals over welded steel stems. Brewster McCracken takes the next exit and, as we pass a shopping center, points out a green-built Home Depot and a solar-powered Chipotle restaurant. Then, as we drive deeper into Mueller, a 711-acre mixed-use development on the site of Austin's old municipal airport, a control tower rises into view above a horizon of tightly packed homes.

CONTINUED ON PAGE 130

Are Green Jobs for Real?

by Joe P. Hasler

From pure optimism to extreme skepticism, few contemporary buzzwords elicit such polarizing emotions as “green jobs.” Proponents say these jobs will ease not only unemployment but also climate change and the nation’s dependence on foreign oil. Skeptics question the sustainability of green jobs and the government’s ability to identify game-changing technologies. By some counts, we can look forward to 5 million green jobs; by others, any surplus will be far outweighed by a net loss of jobs in other fields.

The first step in cutting through the hype surrounding green jobs is simply to define them. Some workers, such as energy auditors and solar-panel installers, have plied their trades for decades. But even jobs in emerging fields, such as smart-grid and electric vehicle development, repurpose age-old professions such as electrician, mechanic and engineer. If



Students in Texas State Technical College's Wind Energy Technology program learn the basics of electricity, mechanics and hydraulics, director Dan Templeton says. And, of course, safety.

Green Jobs Geography

All states have green jobs. But the Clean Energy Economy report, released by the Pew Center on the States in June, attempts to determine how they are distributed across the country and where they demonstrate the greatest growth. This map shows eight states in which the percentage of green jobs exceeds the national average. Some are long-time clean-tech bastions, while others are green upstarts seizing on abundant renewable-energy resources.

OR

- 19,300 green jobs
- 1% of total jobs
- 4.77% annual growth

Oregon's Employment Department projects green jobs will increase 14 percent from 2008 to 2010, largely from organic farming and forestry. Wind giant Vestas is in Portland, as is the Bonneville Power Administration, which is developing ways to handle mass quantities of wind power.

ID

- 4500 green jobs
- 0.63% of total jobs
- 10.11% annual growth

Turbine manufacturer Nordic Windpower recently received a DOE loan guarantee to expand its plant at Pocatello, which is also home to Hoku Materials—a solar materials manufacturer. In eastern Idaho, wind farms operated by Exergy and Ridgeline produce energy not only for Idaho, but also for California, Oregon and Washington.

CA

- 125,000 green jobs
- 0.71% of total jobs
- 0.88% annual growth

Between 2006 and 2008, \$6.6 billion of venture capital poured into the state's clean-tech startups. Home-appliance efficiency standards spurred manufacturing jobs. And a renewable portfolio standard requiring 33 percent renewable power by 2020 has encouraged growth in wind and solar.

CO

- 17,000 green jobs
- 0.64% of total jobs
- 1.98% annual growth

Solix Biofuels, Abound Solar and Ascent Solar are all located in Denver. The National Renewable Energy Laboratory in Golden, Colorado State University in Fort Collins and the University of Colorado in Boulder lead in research and development of clean-energy technologies.

MN

- 20,000 green jobs
- 0.64% of total jobs
- 1.38% annual growth

A growing number of small, eco-friendly manufacturers based in the Twin Cities produce items as varied as nontoxic cleaning supplies, sustainably sourced cabinetry and high-efficiency HVAC systems. The state is home to Mortenson Construction, the nation's largest builder of wind farms. And Xcel Energy, motivated by Gov. Tim Pawlenty's pledge to reach 25 percent renewable power by 2025, continues to develop wind farms across the state.

OH

- 35,200 green jobs
- 0.56% of total jobs
- 0.85% annual growth

In 2002, Ohio's Department of Development launched a grants program to rapidly expand the state's fuel cell industry. Rolls-Royce, based in North Canton, is one of the 70-plus members of Ohio's Fuel Cell Coalition. Once the glass capital of America, Toledo has emerged as a global center for solar manufacturing; 5000 jobs have been added over the past five years.

ME

- 6000 green jobs
- 0.85% of total jobs
- 2.34% annual growth

An aged housing stock means jobs in weatherization and energy auditing. Maine's western ridge is home to four large wind farms, including Stetson Wind, which received \$40 million in stimulus money. Plus, a University of Maine professor says the state's 3500 miles of windy coastline could generate 5000 megawatts and 15,000 jobs.

MA

- 26,700 green jobs
- 0.69% of total jobs
- 0.52% annual growth

Gov. Deval Patrick called for the state to up its solar capacity to 250 megawatts by 2017—and from 2007 to 2008 solar jobs doubled. Construction recently began in Boston on the largest wind-turbine testing facility in the U.S., which will likely attract manufacturers to the state.

diagram by Kako

Green
Jobs
Case
Study

you count all the people working in clean energy, environmentally friendly production, energy efficiency and pollution mitigation—as the Pew Center on the States recently did—and discount the people indirectly linked to those fields, such as accountants, there were 770,000 green jobs in the U.S. in 2007. (Nuclear energy also wasn't counted.) In contrast, there were 1.3 million people working in fossil-fuel sectors.

If measured against every job out there, green jobs account for just 0.49 percent of employment. But Kil Huh, a project director at Pew, says the sector grew rapidly from 1998 to 2007.

During that period the overall economy grew 3.7 percent, while green jobs grew 9.1 percent. And according to the Economic Policy Institute's Ethan Pollack, green jobs tend to be durable and better-paying. "Green investment results in a higher mix of production jobs," Pollack says, "and pushes against a decades-long trend of manufacturing jobs disappearing and low-paying service jobs taking their place."

This initial robust growth was fueled primarily by private investment. Ernst & Young, a firm that provides strategic guidance for clean technology companies, found that as of June 2008, 301 companies in the sector had attracted \$7.3 billion in venture capital. Although the recession caused funding to drop nearly 50 percent in the first three months of 2009 from the same period in 2008—overall venture capital decreased 61 percent, according to Pew—that early boost may help green companies better weather the downturn. "The clean energy economy was one of the few sectors that was better insulated," Huh says. "Because of the increased spending at the federal level, its recovery should be a lot faster."

Roughly \$84 billion of the \$787 billion American Recovery and Reinvestment Act of 2009 has been allocated to initiatives, such as weatherization and battery research, aimed at stimulating green jobs. Already clean tech is showing signs of revival. Ernst & Young found second-quarter venture capital in the sector was up 73 percent from the first quarter, thanks, in part, to confidence stemming from increased government support. Jen Stutsman, a representative for the Department of Energy, which is responsible for disbursing nearly \$37 billion in stimulus money, says a major goal of the Recovery Act was to "catalyze private investors to make investments in projects



A technician makes solar panels at HelioVolt's new factory in Texas. The company took advantage of a workforce trained in the semiconductor industry.

Wisconsin Weatherizer

The new hires in the weatherization unit of the Central Wisconsin Community Action Council (CWCAC) are a motley assemblage of recession refugees. A list of their former professions reads like a who's who of manly labors: auto mechanic, carpenter, roofer, plumber. Adam Faul installed floors for 13 years. But in 2008 projects started drying up and by 2009 he was forced to look for other work. "When the economy nose-dived, I kind of went along with it," he says.

This spring, Faul came across a job listing for the CWCAC, which was hiring six new technicians to help low-income residents reduce their energy costs. The technicians are dispatched to homes, where, acting on recommendations from energy auditors, they install insulation, clean furnaces, seal air leaks, change light bulbs and replace inefficient appliances and windows. With his background in home renovation and experience with power tools, Faul thought it seemed like an ideal new career.

"Most of the guys who transitioned here from other jobs had construction skills, and they wanted to stay in that field because they enjoyed the work," says Brian Bauer, who once installed gutters but now supervises the CWCAC's four three-man weatherization crews. "There was no work left for them. Now they've got stable jobs."

Faul, who started in June, appreciates the stability, but finds the work rewarding in another way too. "It seems like we're really making a difference, like we're part of a bigger picture," he says. "What we do is hard, physical work, but to me it seems different. I don't consider it just another job."

Popular Mechanics

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From high-tech research and development roles to blue-collar work in manufacturing and construction, green jobs run the gamut in pay, education and job description. Some require years of schooling and advanced degrees; many others require only minimum retraining, often provided on the job or in brief but intensive workshops. Community colleges are also rapidly retooling curricula to offer associate degrees in renewable energy systems.

they might not otherwise make now."

Yet some question the government's prescience when it comes to selecting worthy projects. Kenneth Green, a fellow at the American Enterprise Institute, cites the failed attempt to supplant fossil fuels with corn-based ethanol as a prime example of a taxpayer-backed swing-and-miss. "The government is not good at picking winners," he says. Richard Sylla, an economic historian at New York University, points to the Carter administration's attempt to promote solar power. "The government subsidized people to put up solar panels," he says, and when the price of oil came down "a lot of government money was wasted."

But today, Sylla says, things might be different. "Even before the government came in, Wall Street and the venture capital crowd were interested," he says. "Maybe solar power in the 1970s was premature, but 40 years later, it might work." And Alex Klein, a research director at the consulting firm Emerging Energy Research, says the difference between etha-

Fuel Cell Engineer

Description: Focus on improving the efficiency of fuel cells, which generate electricity from hydrogen and oxygen, for both automotive and stationary applications like emergency power. **Training:** Bachelor's degree (minimum) or master's degree (preferred) in chemical, electrical or mechanical engineering for research, design, fabrication and testing. **Salary:** \$50,000 to \$85,000

Smart-Grid Engineer

Description: Develop electrical grids that can effectively distribute power from intermittent sources such as wind and solar, charge a fleet of electric vehicles and communicate through technology that enables homeowners to manage energy costs and utility providers to avoid service disruptions. **Training:** Bachelor's degree (minimum) in systems, electrical or software engineering. **Salary:** \$50,000 to \$100,000

Wind Turbine Machinist

Description: Use machine tools—lathes, milling machines and machining centers—to make gearboxes, shafts, yaw drives and other precisely cut or drilled durable turbine parts. **Training:** Vocational schools, technical colleges and apprenticeships; an easy transition for workers in traditional manufacturing jobs. **Salary:** \$13 to \$25 per hour

Green Architects/Builders

Description: Design and construct buildings that utilize sustainable materials, renewable energy sources and efficient plumbing, lighting and heating/cooling systems. **Training:** The Green Building Certification Institute offers Leadership in Energy and Environmental Design (LEED) accreditation. Various cities and the National Association of Home Builders have unique standards and certification as well. **Salary:** \$50,000 to \$105,000 (architects); \$10 to \$30 per hour (builders)

Energy Auditor

Description: Conduct room-by-room visual examination of structures, examine utility bills, locate air leaks with blower-door tests or infrared imaging, and then prescribe measures to prevent energy waste. **Training:** To audit existing structures, certification from the Building Performance Institute. To assess new construction, certification through the Residential Energy Services Network. **Salary:** \$12 to \$14 per hour

Photovoltaic Installer

Description: Mount solar panels on rooftop racks, configure DC-to-AC inverters and wire PV systems to feed electricity to the grid or to operate as stand-alone power plants. **Training:** Private companies and technical schools offer intensive courses for newcomers. The gold standard for contractors, electricians and those already in the field: A stamp from the North American Board of Certified Energy Practitioners, which also certifies professionals for solar thermal installation. **Salary:** \$14 to \$28 per hour

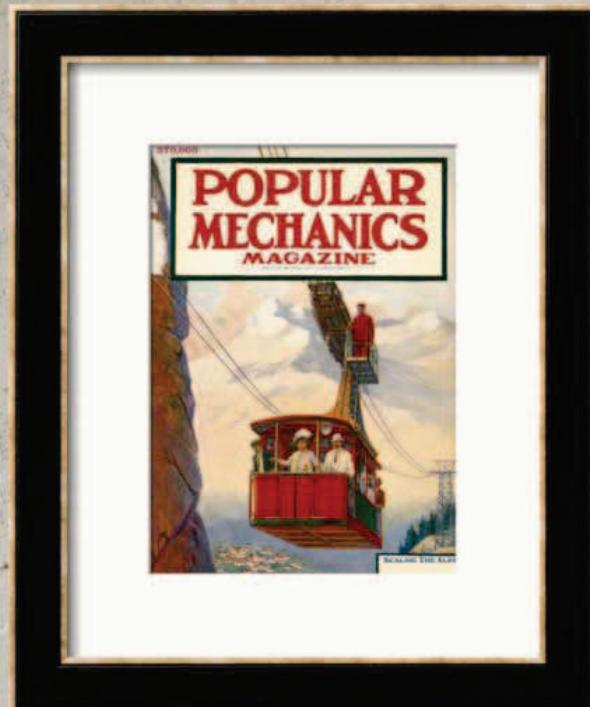
nol and this round of government intervention is that funding is not confined to one nascent technology. Rather, the Recovery Act money—in the form of federal loan guarantees, grants and tax credits—is spread across a broad range of technologies and companies. "They seem to be conscious that if they're spending the taxpayers' money, they're not spending it on projects that aren't coming to fruition," Klein says.

To weed out duds, Stutsman says reviewers from within the DOE, academia and energy fields carefully scrutinize potential awardees. Just how many jobs those projects create—and how many will be long-term—remains to be seen. For now, the green workforce continues to be a tiny fraction of overall employment, making only a slight dent in unemployment. But with clean energy technologies advancing quickly, a genuine green-collar economy may not be far off.

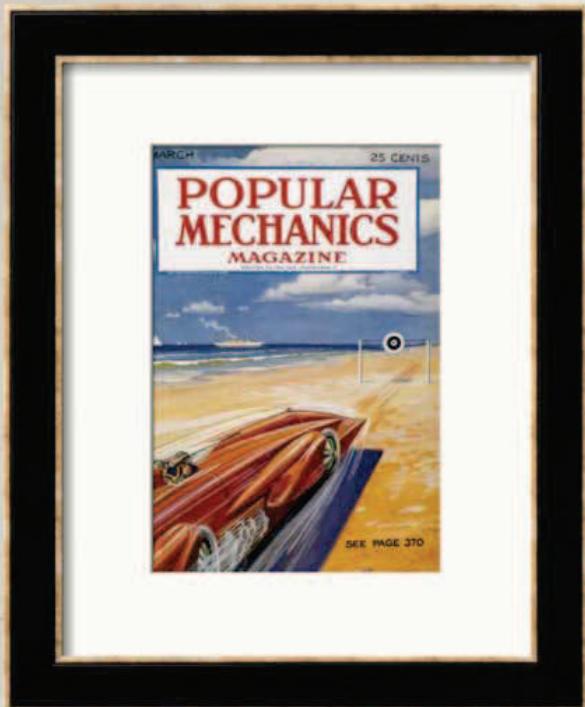
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WE TEST SEVEN CORDLESS DRILLS THAT ARE LIGHTWEIGHT—BUT HEAVY HITTERS. *BY ROY BERENDSOHN*

→ **How much cordless drill** do you need? Probably not as much as you think. We've seen continuous improvement in small drill drivers, especially since the introduction of lithium-ion battery technology. The new crop of 12-volt drills looked promising, but we wanted to know how well they would hold up when we really leaned on them. There's only one way to answer a question like that. We gathered seven drills with nearly identical features. Then we drilled holes with a $\frac{5}{8}$ -inch spade bit and drove 2-inch drywall screws until the batteries gave out. Here's our report.



PM editor Harry Sawyers and two other testers bored 622 holes and drove 1657 screws to test cordless drills.



Number of 2-inch screws:

Number of 5/8-inch holes:

BOSCH MAX LITHEON
PS30-2A

Price: \$150

91

304

CRAFTSMAN NEXTEC
11812

Price: \$90

81

254

HITACHI
DS10DFL

Price: \$100

86

204

MAKITA
DF330DW

Price: \$137

69

162

what we liked

Flat-out screwdriving capacity. That's where the Bosch really shines. It performs as if Bosch's engineers took one of the company's successful full-size drills (tools that have always done well in our tests) and simply scaled it down.

what we didn't

It's small potatoes (maybe even nano potatoes), but the Bosch needs a better grip surface on its chuck ring, and the two-speed slide switch is a little stiff.

**what we liked**

Low price and high performance equal value. That's pretty much the Craftsman in a nutshell. It turned in a respectable performance in the drilling and driving tests, and it's easy to handle, with good grip surfaces and a nice, crisp clutch action.

what we didn't

The action of the forward reverse switch was a bit sticky. You can try switching the drill from forward to reverse and accidentally leave the switch set between the two. Hit the trigger, and it feels like you've got a dead battery.

**what we liked**

The Hitachi is a nimble little drill, thanks to a handle circumference that's almost a half-inch smaller than the other products'. And like full-size drill drivers, it has a box-shaped battery mounted on the end of its handle, making it one of two tools we tested that can reliably stand up. (The other was the Ryobi.)

what we didn't

If a drill as inexpensive as the Craftsman can have a single collar chuck that you don't need two hands to operate, so can this tool. Hitachi should add one. The two-speed selector switch is unnecessarily stiff and uncomfortable to use.

**what we liked**

This was the only 10.8-volt tool in the test. Its smaller battery and motor result in very nimble performance. It's about a half-pound lighter than anything else here, and it's very slim around the handle at the trigger. And while the Makita lacks the overall drilling and driving chops of the other drills, it's the best installer's tool. It's perfect for boring small holes with a twist drill bit and driving or removing machine screws.

what we didn't

The Makita lacks the power of its larger competitors—but that's more an observation than a complaint.



Where Do Your Projects Take You?



Colorado inventor Jason Bailey rides his new "skybike" off the edge of a 125-foot-high cliff with his nine-year-old daughter in the front seat. They soar high over the tops of pine trees while a stream rambles far below. "It's like flying," says Bailey as he pedals the bike along its 450-foot course to the other side of the canyon. "The best seat is in the front; you feel like you're floating through the air with nothing around you."



Bailey designed and built the skybike in his backyard using the PlasmaCAM, a new robotic tool that cuts all sorts of shapes out of metal. "I thought up the idea and drew the design on my computer," says Bailey. "I couldn't believe how easy it was to make all the parts with the machine. It only took a few hours, and fit together perfectly."



The skybike is made of plasma-cut plates attached to simple pieces of square tubing. Bearings, sprockets and other drive parts came from a catalog and an old bike. The machine helped make the seats from 9/16-inch plywood that was covered with foam rubber and seat covers stapled to the plywood. The seats can be quickly pivoted for travel in the opposite direction, and the pedal position is adjustable.



The skybike hangs from a $\frac{1}{2}$ -inch diameter stainless steel cable that is tension-limited to 15,000 pounds. A hydraulic tensioner is used to test the cable at 22,000 pounds before each use. Redundant anchors drilled into rock hold



the cable at each end. All the heavy plates (up to 1-inch-thick) that make up the tensioner, guide the cable, and connect to the anchors were custom designed and fabricated with the PlasmaCAM.



"The PlasmaCAM machine opens up a lot of new possibilities for what you can make," says Bailey. For more information, contact PlasmaCAM, Inc., at (719) 676-2700 or visit www.plasmacam.com.



Number of 2-inch screws:

Number of 5/8-inch holes:

MILWAUKEE M12

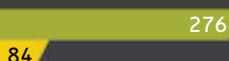
2410-20

Price: \$150

**RIDGID FUEGO**

R82008

Price: \$140

**RYOBI ONE-PLUS**

HJP002K

Price: \$80

**what we liked**

Torque and speed. The Milwaukee has both, and it works faster than anything else, especially when armed with the 5/8-inch spade bit. The extra speed helped throw chips clear while the torque gave it extra oomph to twist the bit through wet wood or areas near knots. Everything about it suggests it was designed for people who work for a living. It's got a big chuck with large numbers, and a handy lighted gauge that indicates battery charge.

what we didn't

If you're like our testers, and occasionally push the drill with one hand on the back of the housing, you cut down on the airflow to the motor through the rear vent.

**what we liked**

If you've got a crowded toolbox, this is your tool. From the chuck to the back of the motor housing, it's 6 1/2 inches long, 1 inch shorter than competitors. And if you're the kind of guy who leans on a drill, you'll appreciate the tool's 250 in.-lb of torque, equaled only by the Milwaukee. That's especially handy if you drill and drive in pressure-treated wood, hardwood or metal. Finally, it had the easiest-turning chuck ring of the seven tools in our test.

what we didn't

Like the Milwaukee, the RIDGID vents air through the rear of the motor housing, and you can inadvertently choke off airflow by pushing the drill with one hand behind the motor.

**what we liked**

We found the Ryobi's no-frills design kind of refreshing. It was the only drill without a speed-selector switch. Its top speed was only 550 rpm, but it slogged along, drilling holes and driving screws. The few features it had were helpful. It was also the only tool with a magnetic bit tray—and not some wimpy thing, either. Put a bit on that tray, and it's there for good.

what we didn't

You need to use two hands to loosen and tighten the chuck around a bit. Given the advent of the single-collar variety, this is outdated.

BOTTOM
LINE

Drill tests are getting tougher to judge because cordless tools keep getting better. All of the products here performed well—beyond our expectations. In fact, the top of the pack was almost too close to call.

If portability and screwdriving are important to you, then these stubby drills probably make more sense than a larger tool. All of them fit more easily into a crowded toolbox than do their 18-volt (or even 14-volt) counterparts. And as our tests prove, they are all relentless drivers.

The real question in deciding how much drill you need is the size and number of the holes you bore, and how quickly you need to bore them. We used a spade bit for our test because it really stresses the tool. If you drill small holes in hardwood and softwood (under 5/8-inch diameter) using a twist drill bit, any one of these tools will serve nicely. For big holes, get a more powerful drill.

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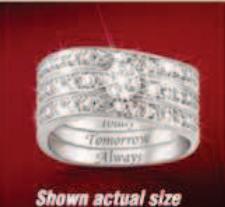
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Homeowners Clinic

by Roy Berendsohn

Q + A



The Big Picture

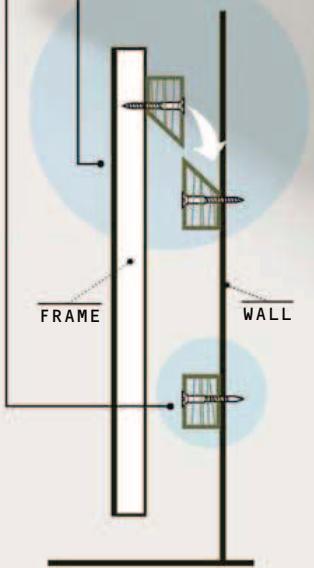
Q I want to hang a large picture in my living room but I can't seem to find heavy-duty hooks to attach to the frame. My local hardware and art-supply stores don't have anything that looks up to the job. My best idea is to drive two large eye screws into the frame and hang the picture off a thick piece of wire stretched between them. Will this hold?

A There's a better way. I'm concerned that if the wire comes loose from one of your screw heads, the picture is going to come crashing down, damaging itself and the floor—and maybe you, as well.

A more reliable method is to use the time-honored French cleat, a system

that uses two beveled lengths of wood. The top block is screwed to the hanging object. The other half is attached to the wall with wood screws. When you place the top half of the cleat over the bottom half, the picture is locked firmly in position. (See the illustration at right.)

To make the cleat, rip two pieces of



ILLUSTRATIONS BY DOGO

wood at an identical angle on a table saw or, lacking that, using a circular saw. The length of the pieces matches the width of what you are hanging. For large pictures, mirrors or cabinets, each cleat should be at least 2 inches wide and $\frac{3}{4}$ inches thick, fastened with 2-inch-long No. 6 or No. 8 wood screws. Assuming $\frac{1}{2}$ -inch thick drywall, each screw would penetrate $\frac{3}{4}$ inches into the framing lumber. That's plenty of holding power for all but the heaviest loads. Of course, if you're sure there's no wiring or plumbing running through the framing and you have a truly heavy load to hang, you can use an even longer screw. Ideally, the bottom cleat should be attached to two studs, with a pair of screws driven into each. If that's not possible, you should still have plenty of holding power by attaching to one stud and using a couple of hollow wall fasteners at the opposite end of the cleat.

One small drawback of the French cleat is that it takes up at least $\frac{1}{2}$ to $\frac{3}{4}$ inch of space behind whatever you're hanging. To keep the object from tipping against the wall, attach a spacer block to the wall or to the back of the frame.

Snowed In

Every year I put up a snow fence, and every year it doesn't seem to do much good. I still get snow drifts on my driveway. Should I bother with the fence again this year?

People often have the wrong idea about snow fences. They don't prevent a drift—they just make the drift form where you want it to. A snow fence slows the wind and causes the snow to drop to the ground. If the fence is correctly positioned, the drift forms where it's out of the way and where it will do the least harm when it melts. The problem comes when people place a snow fence close to walks and driveways. This just ensures that the drifts form in the worst spot—right in the middle of the paved surface.

A rule of thumb for any snow fence: Its distance away from the protected area should be roughly 35 times its height. For a typical 4-foot-high fence, that's at least 140 feet away. Obviously, if that's larger than the size of your yard (and you can't put a fence on your neighbor's property) you should position it as far away as possible. Also consider

planting a row of trees to take the place of a seasonally installed fence. The taller the trees grow, the more effective they become at blocking wind-driven snow.

Leaving a gap between the bottom of the fence and the ground causes the drift to form farther away from the fence, dramatically increasing its effectiveness—the gap prevents the fence from being buried by the drift it creates. For a 4-foot-tall fence, leave a gap of 6 inches or so. Make the gap taller if you are positioning the fence in an area with tall grass and scrubby growth.

Next, the fence should be at least several feet longer than the area it's protecting, to keep snow from blowing around the fence edges. This also helps account for shifts in the wind direction, which range from 30 to 45 degrees.

Finally, to prevent the fence from being torn loose, fasten it upwind of its posts, so the wind pushes the fence against each post, rather than pushing it away. To prevent the fence from being knocked over, brace the posts and support the end with guide wires, especially if the end of the fence is near

a public road where it could be hit by snow from a passing plow.

Discontinued Ducts

I recently changed my furnace and ductwork from a downdraft to an overhead heating system. The old system used ducts that ran through the house's concrete slab floor. We have a high groundwater table, and sometimes the water penetrates the slab and enters the ducts, so I'd like to fill the unused ducts if possible. Would expanding foam work?

Groundwater is a lot like politics: It's all local. Regardless of the water table, you should take steps to reduce water problems around your house before you tackle the ducts. The ground should slope away from the house on all sides, and downspouts should discharge as far as possible from the foundation wall. I'd say that would have to be at

least 10 feet away. Also, contact a foundation drainage company to get an estimate for installing a perimeter drain around the slab.

With that taken care of, you're going to have



■ TOOL NEWS

Cool Inventions, Hot Cash

All of us have ideas for new or improved tools. Some of us take the next step and actually build prototypes. Then the question is, to paraphrase Ralph Waldo Emerson, how does one get a potentially better mousetrap to market and reap the rewards? The DIY Network has one answer with its

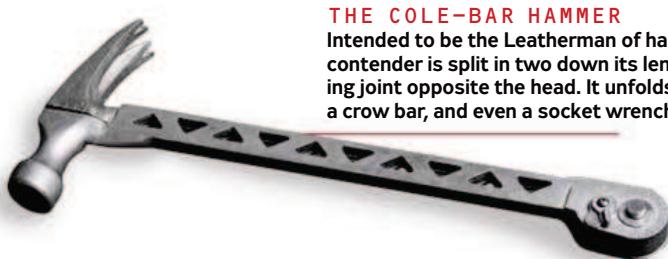
upcoming *Cool Tools Inventor's Challenge* TV special, which airs Thanksgiving weekend. Over 300 backyard tinkerers entered the contest. The ideas ran the gamut from the almost too simple (a small tool-belt hopper that delivers nails to your hand) to a wild contraption that claims to make hanging ceiling

drywall easier. The show picked a handful of the most promising inventions. The finalists will present their products to a panel of three judges that includes PM contributing editor **Chris Grundy**, host of DIY's *Cool Tools*, and myself. The winner gets a cool 10 grand, exposure and, who knows, maybe a coveted spot for his invention on a home center's shelves.

—**LARRY WEBSTER**,
PM Detroit Editor

THE COLE-BAR HAMMER

Intended to be the Leatherman of hammers, this contender is split in two down its length and has a ratcheting joint opposite the head. It unfolds to become a square, a crow bar, and even a socket wrench.



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to hire a professional to deal with the ducts, and even then a pro would likely have to improvise some kind of a solution, whether it's filling the ducts with polyurethane foam or pumping in grout (a cement-based slurry, like thin mortar) or simply capping their ends. There isn't a good by-the-book solution to the problem of failed in-slab ducts. To double-check this, I called PM contributor Pat Porzio, a mechanical engineer, plumber and electrician who's an HVAC contractor. He's seen all kinds of duct systems in his day, and cautioned that the ducts may be a cement-asbestos blend known as Transite. In the old days, some guys would simply hack a ragged hole in the Transite wherever necessary to fit in a floor diffuser. Obviously, if that's the case, you want to cover the duct openings as soon as possible, even if it's with nothing more than a piece of carefully positioned plywood. You can check whether the duct is Transite by snapping off a small piece near a duct opening and sending it to a testing lab in your area.

Regreen Is Very Green

I'm a first-time homeowner, and I've seen a variety of environmental rating systems applied to houses, such as silver, platinum and gold, for example. I'm interested in making my home as eco-friendly as possible, and I'd like it to meet these guidelines. Where do I start the process? You're probably referring to green construction and certification guidelines under the Leadership in Energy and Environmental Design (LEED) program. That's a process in which builders can have a third party certify that a house or commercial building meets a range of ambitious environmental standards. LEED's four levels (certified, silver, platinum and gold) are applied to new construction or to buildings that have been so completely rebuilt that they are essentially new structures.

Since you're talking about an existing structure, your best bet is to look

into regreen guidelines. Regreen is not a certification process. Instead, it's an extremely thorough guide for remodeling contractors and homeowners interested in improving all aspects of a home's environmental performance. The guidelines are the product of a collaboration between the American Society of Interior Designers Foundation and the U.S. Green Building Council (the nonprofit organization that created LEED certification and promotes it).

You can download the guidelines at regreenprogram.org. The document is one of the best of its type that I've seen. In 164 pages, it covers topics ranging from reusing kitchen cabinets to stopping air infiltration through a garage ceiling. Furthermore, it contains numerous links to other sites that can dramatically speed your research into green remodeling.

Steam Ahead?

Would it be possible to repair heel dents in my oak floor by placing a damp cloth over them and using a clothes iron on the high setting to raise the wood grain? This technique worked for me on wood paneling, but I'm concerned it might damage the floor's polyurethane finish.

It's possible you could raise a small dent using the method you describe, but it might do more harm than good. The combination of heat and moisture can wreck a floor's finish. I submitted your question to the technical advisers at the National Wood Flooring Association. Their verdict: Sand the floor to take out the dents.

Red oak is a tough material and it takes a lot of force to dent it. Yet as tough as it is, it can be readily damaged by high heels and other concentrated loads such as the feet of heavy furniture. A variety of studies have found that high heels produce a pressure of several hundred to 2000 psi, depending on weight and the surface area of the heel. Concentrated in a tiny heel, a woman's weight is enough to damage the hollow tubes that

constitute the wood fibers. Picture crushing a soda straw and you get the idea. So, for starters, you may need to refinish the floor. Then you can work on banishing high heels from that room—let us know how that conversation turns out.

Ice Out

Our house is only a few years old, as is its refrigerator. We can't understand why the icemaker behaves so erratically. We've had a technician in to look at it, and he can't find a problem.

I'm willing to bet the refrigerator is connected to the kitchen sink's water filter. Many refrigerators require at least 40 psi of water pressure in order to make ice. The problem is that a filter can cut that pressure substantially, as much as 30 percent if it's a reverse-osmosis type or a clogged carbon filter. When incoming water pressure to the house is only 40 to 50 psi to begin with, that will cause problems for the icemaker. If your refrigerator has a cold-water dispenser, you can test for low pressure by timing how long it takes to fill a typical drinking-water cup. It should take no more than about 20 seconds or so.

Replace the water filter if you suspect that it's clogged, or consider buying a booster pump that will supply the icemaker with water at the correct pressure. (Your refrigerator's owner's manual should specify the correct pump.) Likewise, if the manufacturer recommends against a reverse-osmosis filter, you'll have to install a new piece of supply tubing to bypass the filter.

If the problem isn't a water filter, check the saddle valve that regulates water flow to the refrigerator. The valve is a simple device that clamps over the copper supply tube leading to the icemaker. There are two types. One, called a nonpiercing (or drill) type, requires that a hole be drilled into the supply tube before the valve is installed. The other is known as a self-tapping saddle valve. It has a pointed tip that punctures the tube. "The hole created by these self-tapping valves is much smaller than the drilled hole," says Chris Zeisler, a repair technician

with *repairclinic.com*, a Web-based appliance-parts retailer. "Thus, the self-piercing valve is prone to plugging from mineral or other deposits. They shouldn't be used in icemaker installations." Replacing the valve with a non-piercing or drill-type valve may well solve the problem.

Crumbling Concrete

The surface of my concrete driveway is crumbling because of road salt. Can I use a sealer on it to prevent further crumbling?

The condition you describe is known as scaling, and before you slather on the sealer, you should get some professional advice from a local company that specializes in concrete restoration and finishing.

That probably sounds like drastic advice for such a simple-sounding question, but there's good reason for it. Exterior concrete is supposed to be able to withstand normal de-icer chemicals. When it doesn't, that could mean several things, none of them good: Either the concrete wasn't produced with an air-entraining cement or a similar admixture, it wasn't properly finished, or it wasn't properly cured. (Air-entrained concrete contains microscopic air bubbles—as many as 300 to 500 billion per cubic yard, according to the Portland Cement Association. The voids allow ice crystals to form, then melt and reform without damaging the concrete's surface.)

If the damage is spreading, and it likely will, a concrete restoration company will know the best overlay to deal with it in your region and climate, as well as how to prepare the driveway prior to applying an overlay. The restoration experts may also recommend a sealer to reduce water penetration through the surface. **PM**

Got a home-maintenance or repair problem? Ask Roy about it.
Send your questions to pmhomeclinic@hearst.com or to Homeowners Clinic, Popular Mechanics, 300 W. 57th St., New York, NY 10019-5899. While we cannot answer questions individually, problems of general interest will be discussed in the column.

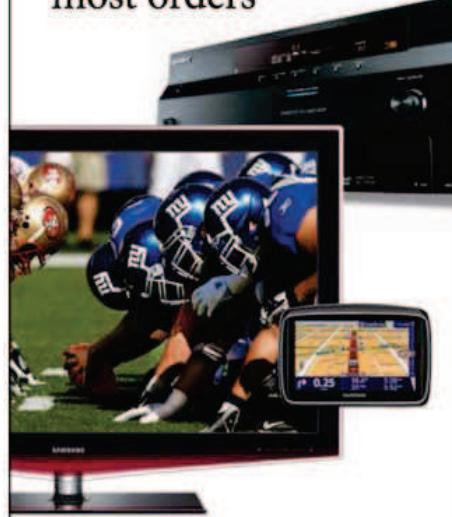
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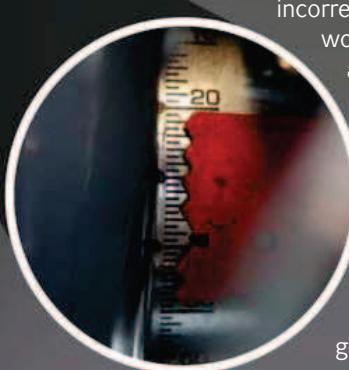
This Chevy V8 uses an old-school Kettering-style ignition distributor. To set the timing after replacing the points and condenser, you'll need, no surprise, an old-fashioned stroboscopic timing light.

Old-School Ignition Tech

GOT A COLLECTOR CAR WITH IGNITION POINTS? HERE'S HOW TO REPLACE THE POINTS AND SET THE TIMING. *BY MIKE ALLEN*

→ **"It's not a heap, dad.** It's a classic." That's harder to justify when your classic muscle car won't start. Nothing like a high-compression V8 combined with a battery that hasn't seen a charge for a month and a half to make for slow cranking. Add in the indifferent, low-energy spark and incorrect ignition timing caused by worn-out points, and you've got an engine that won't fire—oh, and wet spark plugs too.

Modern engines use computer-controlled factory-preset self-adjusting ignition systems that never change their timing, have no moving parts and never need maintenance. Yay! A generation ago, every teenager,

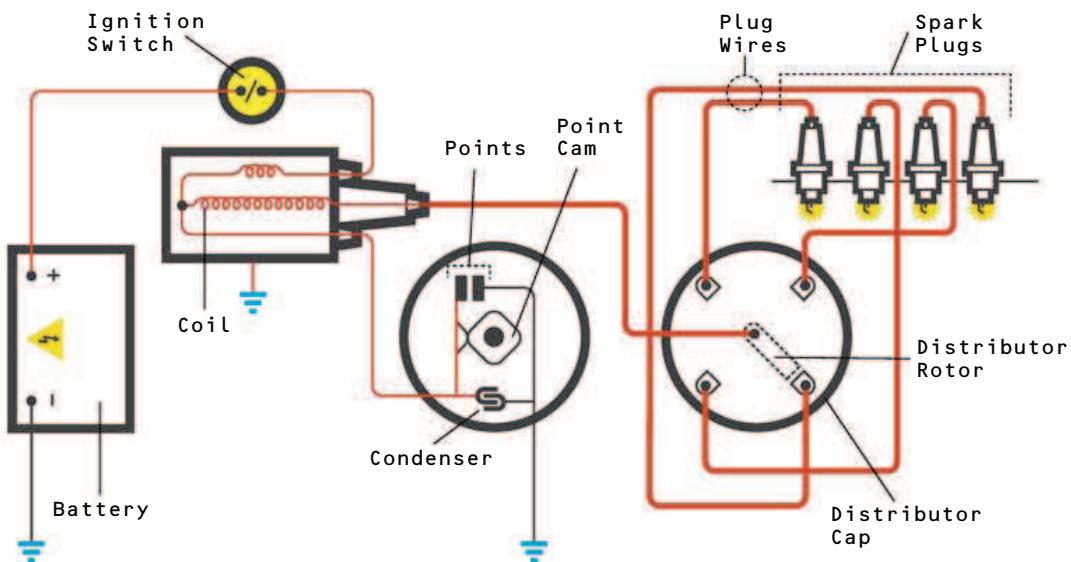


every mechanic and a lot of vehicle owners understood the theory and practice of changing points and setting the timing. Nonetheless, there are still plenty of older vehicles, outdoor power equipment, boats and tractors that need periodic adjustment or replacement.

The distributor on these older vehicles performs two related tasks. The first uses a simple on/off switch, the ignition points, to provide properly timed pulses of 12-volt electricity to the ignition coil. In the coil, essentially a transformer, it's stepped up to 10,000 to 20,000 volts. Then, the high-voltage electricity from the coil returns to the distributor, where the rotor inside parcels it out to the correct spark plug to ignite the fuel/air mix.

There's a lobed cam on the distributor shaft that pushes on a small rubbing block on the movable side of the points. As the cam and distributor rotate, the points open and close constantly. As they close, current from the ignition switch flows through the contacts into the coil's primary windings and then off to ground. This current generates a magnetic field in the coil's iron core. When the points open a few degrees of crankshaft rotation later, the current is interrupted, causing the magnetic field to collapse. This induces electrical current into the secondary windings of the coil, where the current is raised to 20,000 volts or more. The high voltage now travels over to the distributor, where the rotor metes the high-voltage pulses out to the correct spark plug.

All that current flowing across the points doesn't like to stop suddenly, and can initiate a small arc, which eventually erodes the tungsten contacts. The condenser cushions that arc, making point life much longer. But not infinitely long. As the contacts and the plastic rubbing



↑ Kettering Ignition

Charles F. "Boss" Kettering was one of the founders of Delco, and the inventor of the battery-point-style ignition system, first used by Cadillac in 1910. Wear, inaccuracy and high maintenance have forced car manufacturers to abandon this system, replacing it with computers and individual ignition coils for every cylinder—and no points to wear out.

block, which contacts the point cam, wear, the ignition points' clearance and timing constantly change. After thousands of miles, the timing has shifted enough to affect performance, and the ritual of changing the points and setting the timing becomes necessary. How often? Some vehicles need to have the timing adjusted as often as every 10,000 miles to maintain peak performance. High-revving engines will need premium points with a high-pressure spring to keep the points from bouncing at increased revs. Some points assemblies include the condenser, yet for others, it's a separate part. Condensers are inexpensive enough that it makes no sense not to replace them with every set of points. They should last as long as a set of points, 20,000 miles at least.

On Point

→ **The function of the ignition** system is to fire the spark plugs at the correct time, just before the piston hits top dead center (TDC) on the compression stroke, to ignite the fuel/air mixture, thence producing high pressure in the

cylinder to force the piston down and, subsequently, the wheels to move the car forward. The spark plug normally fires anywhere from 10 to 45 degrees before the piston reaches TDC, to allow the fuel/air mixture's flame front to traverse the combustion chamber. It takes a few milliseconds for the pressure in the cylinder to build, and waiting until TDC would make the pressure peak too late in the piston's downward stroke to be most efficient. Under some engine-operating conditions, the advance might adjust the ignition timing to as much as 45 degrees before TDC. Signs of incorrect ignition timing include hard starting, spark knock, poor power, overheating and decreased fuel economy.

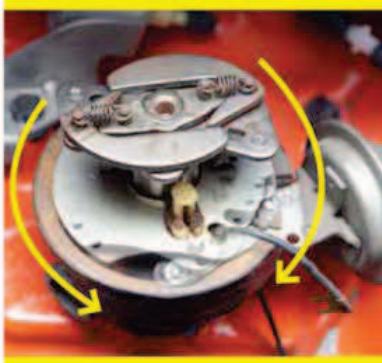
Advanced Timing

→ **There are two main types** of advance mechanism built into the distributor. The first is the centrifugal advance. A pair of bob-weights spin atop the distributor shaft, restrained by small springs. As the engine speeds up, centrifugal force pulls the weights outward, which in turn makes the top



◀ MECHANICAL ADVANCE

These spring-loaded counterweights move farther out as the rpm increase, advancing the ignition timing. How much advance and how early is determined by the springs.



◀ VACUUM ADVANCE

Vacuum from the carburetor pulls on a rubber diaphragm to rotate the breaker plate for extra ignition advance at part-throttle. Be sure both these advance mechanisms are working whenever you replace points.



→ Setting Dwell

Changing the clearance in the points affects the proportion of time the points are closed ("dwell") and the charging of the coil. A dwell meter is needed to properly adjust the dwell angle, which is done with the engine spinning on the starter motor or, on some engines, actually idling.

of the split distributor shaft advance. Missing springs or a gummed-up linkage can give too much advance too soon, or none at all.

Similarly, a vacuum advance uses a rubber diaphragm to advance or retard the timing. Vacuum from the carburetor pulls on one side of the diaphragm, pulling the points around the distributor and making the plugs fire earlier. A leaky vacuum line, a disintegrating rubber diaphragm or a sticky breaker plate can make the advance mechanism balky.

Inoperative advance mechanisms can deliver too much or too little ignition advance. Too much advance can make the engine ping. Too little causes power loss and overheating.

Installing the new points and condenser is simple, and usually requires no more than a screwdriver. The proportion of time the distributor's cam keeps the points closed and open is referred to as dwell angle. Adjust the dwell angle initially by using a feeler gauge. Most V8 American iron should be adjusted to 0.018 to 0.020 inches, while four-cylinder engines, like early VWs, start

around 0.014 inches. Close is good enough, because the only really accurate way to set dwell is with a—wait for it—dwell meter. The dwell angle should be 30 to 35 degrees for V8s and 44 to 50 degrees for four-cylinder engines. Check the shop manual for your car. Attach the dwell meter to the coil's low-voltage leads and spin the engine with the starter motor to check and trim the dwell. Some cars have a small window in the distributor to let you set dwell with the car running, a real timesaver because you don't have to crank the engine with the starter, adjust the points and check the dwell again.

Cleanup in Bay 4

► **Before you button up** the distributor, clean the point contacts of any oil left behind by your feeler gauges. Contamination will carbonize and become a resistance where there should be only metal-to-metal contact. I usually just use the corner of a business card to scrub any contamination off. Add a dab of point-cam lube to the rubbing block.

Adjusting dwell also changes the

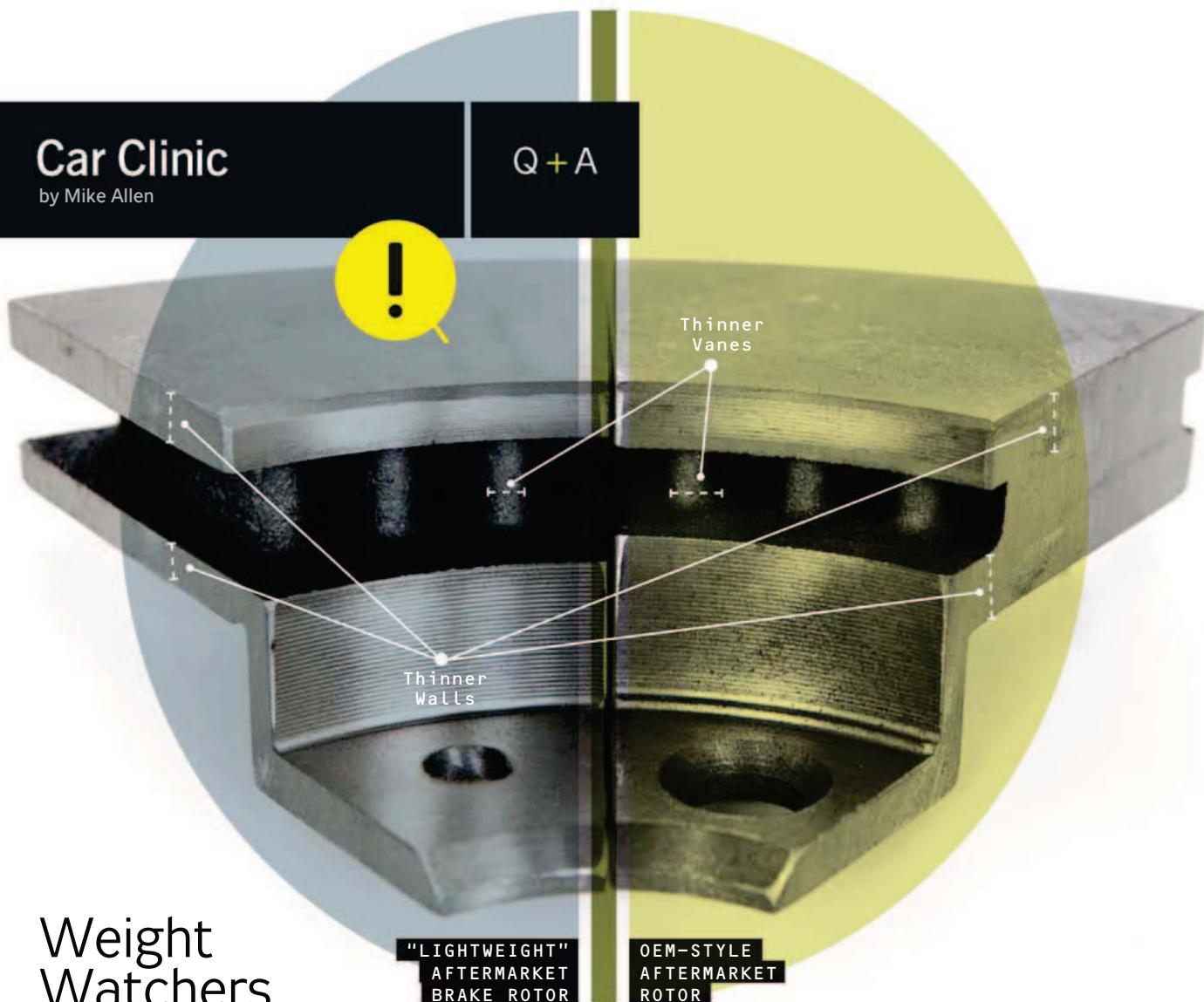
base ignition timing, so whenever the dwell is adjusted or the points replaced, the timing will need to be adjusted. Some engines call for vacuum lines to be pinched off or disconnected, so you'll need to find the correct timing procedure for your engine in the shop manual. I'll wait ...

Got the timing specs? Find the timing marks on the harmonic balancer or on the flywheel. Use some contrasting paint or a felt pen to brighten the timing mark. Hook the timing light to the No. 1 plug wire. Start the engine, and shine the timing light at the timing marks. Mind the whirling fan and the belts, reminds my old-timer mechanic pal Lefty. The strobing light will "stop" the spinning pulley when the No. 1 plug fires. Loosen the clamp holding the distributor down and slightly rotate the body of the distributor to line up the timing marks. Revving the engine slightly should make the mechanical advance actuate—you'll see the timing marks advance and retreat as the engine surges. Tighten the distributor clamp, reconnect any vacuum lines and drive.

Car Clinic

by Mike Allen

Q + A



Weight Watchers

Q I needed new disc brakes for my car, but the repair shop wanted so much money for the parts alone, I went to the auto parts store up the street and bought them myself. But when I showed up at the shop to have them do the installation, the manager took one look and refused to install the brakes. He said they were poor "offshore knockoffs," and likely to kill me and my family. I was a little annoyed—until we both calmed down and he showed me the difference in the parts. The ones I bought were much lighter, because the metal was thinner at almost every spot. So I took them back. The parts-store clerk said these were special "lightweight" brakes, and would actually help me save gas. They wouldn't refund my money, but would let me swap them for a different set identical to the ones the brake shop wanted to install, right down to the brand on the box—and they wound up costing me more than the brake shop would have charged me in the first place. Is it legal to sell these lightweight brakes?

Lighter isn't better.

Reducing the mass of cast iron in brake discs is one way to trim costs, but it comes at a reduction in brake performance.

A Legal, yes. As to their being lightweight, they certainly are. A good idea? Probably not. There are increasing numbers of these offshore, low-quality brake discs showing up on shelves lately. They use less cast iron and have thinner flanges and fewer, thinner cooling vanes than the OEM equivalents. Brakes transform the kinetic energy in your vehicle to heat. It takes mass, in the form of that cast iron, to capture the heat, and then surface area to dissipate the heat to the air. Less mass equals poorer brake performance in high-speed stops. Fewer vanes equals poorer performance in sequential stops or on long downhill grades. In both cases, that's bad, dude. The failure mode here is when the friction material gets hot enough to boil,

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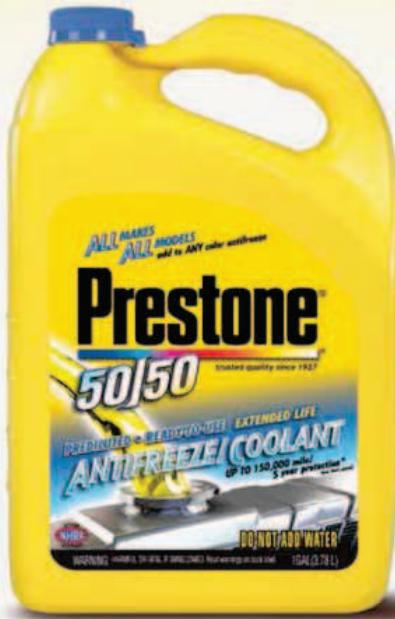
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forcing the pad surface to float above the iron discs on a grounds-effect cushion of vaporized binder, leaving you with a spongy pedal and no braking power. Extreme cases of overheating can boil the brake fluid, leaving you with no brakes until they cool.

There are a half-dozen manufacturers of brake discs in this country, and more overseas, that make discs virtually indistinguishable in quality from the ones installed on your car the day it was made. Stick to brand names, and you should be fine. Saving money on brakes somehow doesn't sound like a good idea, especially when the difference is only 20 or 30 bucks. As for saving gas because the discs are lighter? I don't think so.

Slow Hand

Is there a way to repair a seatbelt retractor? I have a relatively new

SUV with seatbelts that are slow to retract. The belts require a little help so that they don't get caught in the door when we get out. Can they be lubricated?

I've fixed a bunch of seatbelt retractors. Usually, they are gummed up by lint, dog hair, and in one case what seemed to be the majority of a bottle of sticky soda.

Warning: Do not attempt this if your vehicle uses seatbelt pretensioners, which are more complicated, and are, in some cases, driven by the same kind of pyrotechnics as an airbag.

Remove the seatbelt retractor from its mounting, which will probably mean removing some interior trim. Don't remove the belt's webbing, or you stand the chance of letting the whole thing unwind like a cheap window blind. Clean as much gummy lubricant and dirt out of the

NOW YOU KNOW Sync Is Calling

What does that light on my dash mean? You know, that Check Engine light that only the mechanic can decipher, requiring a trip to the shop and a \$75 fee just to look? Either that, or buying a scan tool—and then try to figure out what "Code P0300" means in Earth language. Ford's 2010 Sync system, as well as syncing your iPod and your phone to the car, can short-circuit (sorry) all of that. All you need to do is activate a

Your car can send e-mail. Kewl.

feature called Vehicle Health Report, then Sync your Bluetooth phone and perform a Vehicle Health Report. If the Check Engine light comes on, Sync will send you a quick e-mail detailing the problem in lay terms, letting you know that a P0300 is

just a generic code for a misfire, and that your car won't explode before you get home. Sync will even volunteer to make an appointment with the local Ford dealer for a repair. Sounds like just what I need to keep track of my wife's car when I'm out of town.



mechanism as you can with a toothbrush or some innocuous cleaner such as Simple Green. Solvents or harsh cleaners like ammonia or detergents may degrade the nylon webbing, which would be bad. Lubricate sparingly with silicone spray. If the mechanism permits, you may be able to lube with some silicone grease or lithium grease, but, again, avoid getting any on the webbing. If you feel really confident about tinkering with such a vital safety system, disassemble the whole shootin' match and wind a couple of extra turns into the clock spring that operates the retractor. But if you've ever redone the spring mechanism in a lawnmower recoil starter, you'll avoid this at all costs.

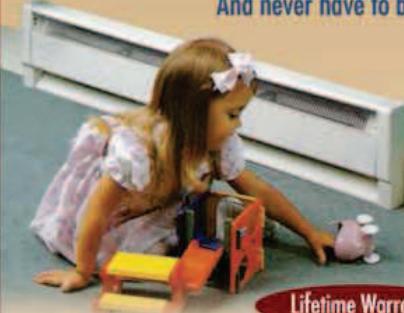
Cheap Insurance

I have a 1998 New Beetle TDI (diesel) that had its Check Engine light come on. A VW dealer found a rust-frozen wastegate rod. He lubed it and moved it back and forth. However, he said the problem would probably come back. Since the part is not available separately from VW, I would have to buy the entire turbocharger. Installed, that will run a whopping \$2200. Is there a way of getting only the offending part and replacing just that? Will running the engine this way damage anything?

The wastegate bleeds off excess exhaust from the turbo to keep the intake-manifold pressure from getting too high. Just because the part isn't available directly from VW doesn't mean it's unavailable. Hunt around for the part instead of just believing what the dealership tells you. And, frankly, freeing up and oiling a moving part once every 10 years sounds like the cheapest solution. Maybe, if you lubed this part annually with a

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penny's worth of Nevr-Seez, it wouldn't freeze up again.

Will not fixing this damage your engine? Depends. If it sticks open, dumping the wastegate all the time, you'll have little power. If it sticks closed, you could overboost the engine and melt or break a piston.

Lights Off

My Ford Explorer's battery was drawn completely dead by the interior lights when someone left the door ajar for a full week. Can I jump-start my Explorer with cables and drive 100 miles without damaging the alternator? I have been warned that the alternator will be damaged.

I know, I know; we've all jump-started cars many times and haven't damaged anything yet, right? On the other hand, the large amount of current needed to operate late-model cars with electric fuel pumps, fuel injection and gobs of electricity-consuming accessories is daunting. That's why most cars have 100-amp or larger alternators. Running all that stuff while trying to resuscitate a really dead battery can make an alternator overheat. Black, crispy wiring = bad. Alternator manufacturer Bosch warns that alternators can indeed be damaged this way. A decent charger is less than a new alternator.

To reduce the current your poor alternator is going to have to produce to charge that battery, Bosch—and I—recommend charging the battery 3 to 4 hours with a proper battery charger before starting the car. If that's not feasible, do this: Start by hooking up the jumper cables to the two batteries and letting them chat for a half-hour or so. Don't run the engine on the donor car. This will put at least some charge into the dead battery. Then start the donor car and let it run at fast idle for 10 to 15 minutes to add some more charge. Now start the dead car, but turn off as many accessories as you can. Specifically, don't use the air conditioning, headlights, rear-window defrosters or any other high-power devices until the car has been driven for a couple of

hours. Drive, if possible, on the freeway, or at least avoid stop-and-go traffic. You'll be better off with the engine spinning and the alternator's cooling fan spinning along rapidly to keep the alternator from frying itself. Start saving money in the cookie jar for a new battery. Deep-discharging a flooded-cell lead-acid car battery like yours, even once, will permanently damage it.

Torque to Me

I am changing the front struts on my '05 Ford Explorer. The manual says I need to torque the bolt that mates the strut to the lower control arm to 258 ft-lb. I looked everywhere for a big enough torque wrench. It looks like all the torque wrenches peak at 250 ft-lb! I also researched impact wrenches, and they have the torque required, but I wonder if they're accurate.

An impact wrench is not an acceptable way to torque anything, even a lug nut. There are larger torque wrenches, but you'd need to go to an auto parts store or an industrial supply house. For serious torquing, they make gear-driven torque multipliers that can increase the torque value on the wrench by as much as eightfold. Of course, that's overkill for your job. I would just set the torque wrench to 250 ft-lb, and give it one tiny twist more after the click. For that matter, the difference between 250 and 258 ft-lb is about 3 percent, and I doubt the wrench calibration is closer than that.

Not fastidious enough for you? Let's try this. Put an open-end crowfoot on the end of the torque wrench instead of a socket, which will extend the wrench about three-quarters of an inch. My half-inch torque wrench is

about 14 inches long from the center of the drive to the pivot on the handle. Adding the crowfoot will multiply the torque by $14.75/14$, or a little more than 105 percent. Measure your crowfoot and wrench to find the specific multiplier for your application. If you were to make or buy an extension that moved the torque wrench back exactly 14 inches, then the torque on the bolt would be exactly double what the wrench is set to. Sometimes, I just use a combination wrench as a torque multiplier. Do the math to figure what you need to dial up on the wrench to achieve the correct fastener torque.

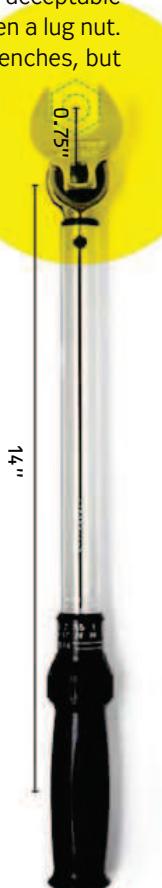
Diesel Woes

I own a 2009 Jetta TDI like your long-term test car (in the August '09 issue). I too had the experience of purchasing contaminated fuel. I fueled up my car with diesel and as I was leaving it sounded like I was dragging chains. By the time I went to exit the service station the car was nonfunctional. I had it towed to the nearest VW dealer and was told that I had contaminated fuel. But, unlike your test car, I had to pay \$450 to have the fuel system flushed out.

Gasoline burns far more rapidly than diesel, and the chain-like noise you heard was detonation, similar to the ping you get in a gas engine running on low-octane fuel. Continued operation under these conditions could damage your engine, so be glad it shut down right away.

Obviously, somewhere along the distribution chain, gas got mixed with diesel fuel. That gas station owes you \$450 and the cost of the tow. You, and a lot of other people who pumped fuel from that tank. Call whatever state or county agency regulates gas stations in your area and complain. Then call your attorney.

PM



Got a car problem?

Ask **Mike** about it. Send your questions to pmautoclinic@hearst.com or to Car Clinic, Popular Mechanics, 300 W. 57th St., New York, NY 10019-5899. While we cannot answer questions individually, problems of general interest will be discussed in the column.



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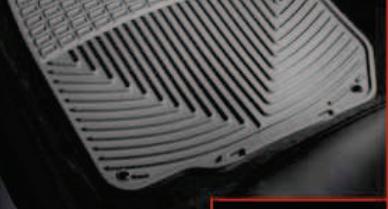
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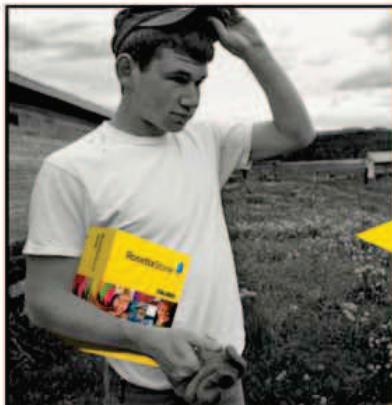
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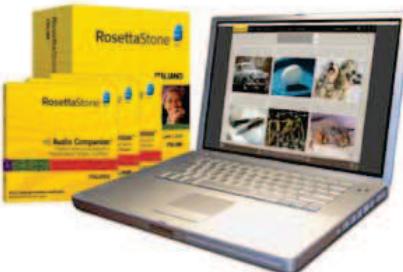
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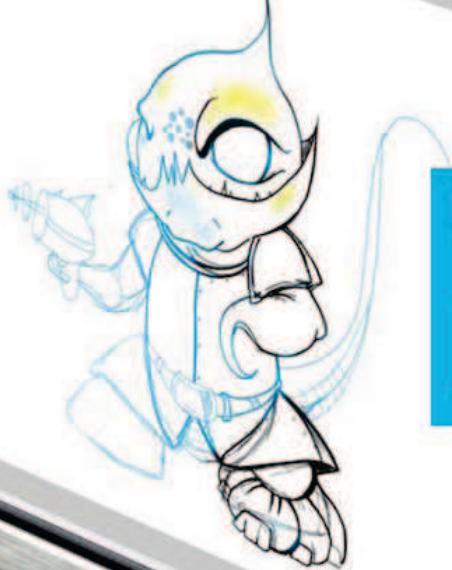
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INFINITI JOURNEY OF INSPIRATION

The Infiniti Journey of Inspiration debuted at the 59th Annual Pebble Beach Concours d'Elegance. The event was an immersive visual exploration of Infiniti's new luxury performance vehicles, showcasing the North American reveal of the Infiniti Essence, as well as a virtual video map unveiling of the new **Infiniti M**. See The Journey of Inspiration, a special section in this issue, to experience the event.



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DIY Tech

Digital Sketchbook

THE TECHNOLOGY TO TRANSLATE YOUR DOODLES TO PIXELS IS SURPRISINGLY AFFORDABLE AND ACCESSIBLE. *BY ANTHONY VERDUCCI*

→ **Drawing**, that medium of pencils, pens and paper, would seem to be the last great analog art. Traditional sketching is a tactile experience that doesn't translate well to a mouse. But take the mouse out of the equation and replace it with a digital pen, and drawing on a computer becomes a surprisingly intuitive experience.

Pen-based user interfaces are almost as old as computing itself, but professional graphic artists all swear by one technology—the Wacom tablet and pen. Wacom makes a variety of pen and tablet interfaces, from \$2000 21-inch rotating tablets with integrated screens to the small, consumer-friendly Bamboo Craft, which sells for \$130.

I've used Wacom tablets both professionally for photo retouching and for my hobby, creating cartoon creatures, for years, but the fundamentals of the

pen interface take only minutes to learn. A Wacom tablet interacts with an electromagnetic resonance pen that the pad can detect from up to a half-inch away. You can control the onscreen cursor by hovering above the pad's surface. To draw or select an option, just trace or tap on the pad. The tablet senses both pressure and directionality, so it can digitally mimic the character of your stroke—from the gentle scratches of a pencil to the thick, heavy lines of a paintbrush dragged across a canvas. Newer Wacom tablets, such as the Bamboo Craft, are two-finger touch-sensitive, meaning you can use the device as a digital drawing pad as well as a trackpad replacement for a mouse.

The second part of the artistic equation is software. No two artists have the same style or technique, and just as analog artists work in acrylics, watercolors, oils or inks, digital artists have a broad tool set of art programs available to them. Pro art software is enormously capable, but can get expensive and eye-glazingly complex. Adobe Photoshop (\$700), for instance, has artistic tools that go way beyond its core photo-manipulation functionality. Corel Painter (\$500) digitally mimics the process of using traditional media such as oil and pastels. And Autodesk Maya (\$3495) is sophisticated 3D modeling software. But any of these programs can take years to master.

For newbies, many of the same companies that make pro software also have lower-priced programs such as Adobe's Photoshop Elements (\$100), Corel's Painter Essentials (\$100) and Sketch Pad (\$120), and Autodesk SketchBook Pro (\$100). These are easier to learn and far friendlier to the wallet. (Wacom tablets generally come with two free art software downloads, so some of these programs can be had for no cost.) The software that fits your style is best discovered through experimentation. Download trial versions of software before you buy.

Most of these programs have a fairly similar logic and set of tools. The concept of layering, for example, is perva-

sive. Drawing and editing images in layers is like having infinite levels of tracing paper to compose your image with. You can draw a rough sketch on the bottom layer, then progressively refine it and add color in successive layers (see "The Layered Look"). As you work, you can turn individual layers on and off, allowing you to experiment without losing your previous work. Don't like your character's hands? Turn that layer off and try drawing a set of lobster claws.

Palettes of tools such as paintbrushes, pencils, chalks and airbrushes are common to most software; colors can be mixed on screen and brush sizes and shapes dialed in to your specification. Some software even allows you to specify the character of the paper or canvas you are working on. The more you explore each program, the more functionality you'll discover. And you can use different programs in tandem. A drawing started in Painter Essentials can be opened in Photoshop Express, where you can tinker with new effects.

Once you start experimenting, you'll find plenty of options that are easy in the digital world but would have been painstaking or even impossible in the physical world. For instance, you can take a digital photo, import it as a source layer in Painter, trace over it and end up with a photo-accurate illustration. (If you don't want to import the photo digitally, lay a printout over your tablet and trace directly over it.)

Any mistakes are easily erased, and as you work, you are constantly creating scenery, characters and other elements that you can cut and paste into new work. For my creatures, I have a library of perfectly executed alien heads, serpent eyes, claws, hooves and various antennae that I go back to all the time.

When you get good enough, you can print your work directly to canvas using online services such as Canvas On Demand or Canvas People, and then put them up for sale at etsy.com. Or you can make T-shirts and mugs and sell them at cafepress.com. Just because you're an artist doesn't mean you have to starve.

STEP BY STEP

The Layered Look

Digital artwork is created through a layering process. Each layer refines the one below it, like tracing paper. This structured drawing process allows much more flexibility and room for experimentation.



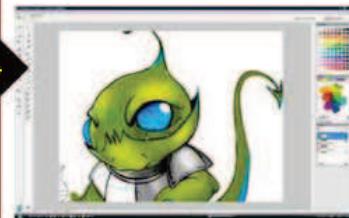
The base layer is for brainstorming with a light-colored pencil tool. Use the space to rough out multiple ideas.



Pick out your best ideas and redraw them into the next layer. Refine the details of your subject and decide on your point of view.



Add another layer underneath the sketch layer for color. Experiment with various brushes and tools to add texture.



On the uppermost layer, trace over your sketch with the pen tool to create a solid outline. Add in fine details like wrinkles, shadows and highlights.

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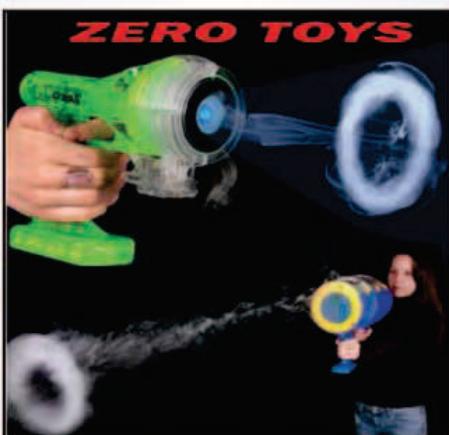
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Digital Clinic

by Seth Porges

The Cellphone Freeze Test

Q I live in a cold climate. Can my cellphone get damaged if I leave it in a car or bag on a frigid day?

A People tend to assume that extreme cold and mobile devices just don't mix. After all, cold temperatures can freeze liquid-crystal displays and slow the chemical reaction that gives lithium-ion batteries their charge.

But bringing phones into the cold is unavoidable—if you've ever gone skiing, or you simply live in Chicago, you've certainly spent hours in a freezing environment with nothing more than a layer of denim or a jacket pocket to shield your phone from the chill.

Exactly how cold can a phone get before it stops working? We decided to find out. For help, we called up our friends at Environ Laboratories, an environmental testing facility in Minneapolis used by the defense, aerospace and technology industries to simulate extreme conditions. We gave Environ a sample of six phones from various manufacturers. These models were the type of commodity phones that service providers often give away for free with new contracts—none was billed as "ruggedized" or designed to withstand extreme temperatures. Environ's job was to freeze the gadgets in a temperature-controlled chamber (lowest possible setting: minus 100 F) until all six phones stopped working—no matter how much cold that required. In other words, we decided to push these phones way beyond the limits of their design parameters and warranties.

Beginning at 40 F (the equivalent of a brisk autumn evening in New England), we let each phone run for 30

Q+A



minutes before bringing the temperature down by 10 degrees. We repeated this incremental temperature drop every half-hour until the phones stopped working. Once a phone died, we gave it one last dash of mercy by bringing it back to room temperature to see if warmth could revive it.

Other than minor hiccups (slight screen dimming, slow key response),

none of the phones had any real problems down to minus 10 F, when the low-battery indicator popped up on one Samsung, despite the fact that it had recently been charged. At minus 20, the same phone shut off (plugging it in and turning it on quickly revived it), and the displays of some of the other phones were difficult to read.

Thirty below is where the real

ILLUSTRATIONS BY DOGO

-55°



It took four dunks in liquid nitrogen—and a hard throw to the floor—to finally kill our Motorola Krzr.

fun began, with five of the six phones experiencing serious battery or LCD problems—the display on a Nokia became an unreadable block of blue, while bizarre bars polluted another phone's screen.

Another 10 degrees, down to minus 40, and all but one of the phones was rendered inoperable. The last phone standing, an old Motorola Krzr belonging to a PM staffer, actually remained functional until about minus 55 F, when its battery died.

Remarkably, none of the damage appeared to be permanent—all it took was a return to room temperature to bring all of the phones back to life.

Still, we're electronic sadists, and we weren't going to let our access to Environ's environmental testing facility—and its vats of liquid nitrogen—go to waste. Sure, the coldest temperature ever recorded on earth was just minus 128.6 F (and the continental U.S. has never dropped below minus 70) but we couldn't resist finding out how our toughest competitor could handle a dunk in a minus 314.7 F bucket of liquid nitrogen.

Amazingly, the Motorola phone survived multiple dips in the coolant. The sub-sub-zero swims caused its battery to shut down, but once the phone was warmed up, it came back to life with no visible damage. We even dropped the frozen phone to the floor from hip height. And although we expected it to shatter, the fall barely caused any damage. In fact, it wasn't until we dunked the Krzr in the liquid nitrogen four times, and then forcibly threw it to the ground, that it finally

called it quits. Even then, the screen still turned on when the phone was plugged in (although it was unreadable), and, amazingly, the audio still worked. Some keys even appeared to produce a response.

The results were reassuring, if not astonishing. The bottom line: Alaska residents might endure some screen problems or short-lived batteries on cold days, but nothing a warm room couldn't

cure. And if our phone can handle repeated swims in one of the coldest liquids on earth, yours can surely survive a day on the slopes without worry.

Leopard Spots

I want to upgrade my Mac to the new Snow Leopard operating system. Will all of my existing applications be compatible with the new OS?

The new Mac OS X version 10.6, better known as Snow Leopard, is a sort of guerrilla update. It's inexpensive (users can upgrade to it for as little as \$29), and does virtually nothing to change the look and feel of your computer. In fact, most of its changes are under the hood—it uses several gigabytes less hard-drive space than its predecessor, and it should help your whole system run a bit faster.

While most existing programs will work just fine on Snow Leopard, a handful have experienced problems (at least in their current iterations). When you install Snow Leopard, your computer will automatically move these applications to a new folder called Incompatible Software.

Thankfully, Apple has published a list of known problem programs on its website (check under "Support"). So while you probably have nothing to worry about compatibility-wise, it's a good idea to check this list before upgrading, just to make sure that nothing you rely on will be put out of commission.

Automatic Auto-Tune

I'm into making my own music and have tried using Auto-Tune software to modulate my voice to sound like T-Pain or Kanye West. Trouble is, the software seems fairly complex. Is there an easier way of doing it?

Auto-Tune software has long been used by recording artists to nail wayward vocal tracks to a precise pitch. But cranked to the max, the software has the intriguing (and potentially annoying) ability to make people sound like musical robots. (You might recognize it from Cher's "Believe," which was one of the first hits to make large use of the effect, and nearly all of Kanye West's 808s & Heartbreak album was recorded with it.)

Still, it can be fun to tinker with Auto-Tune, especially if you're tone-deaf, like me. The easiest way to play with the effect: a new iPhone app, appropriately called I Am T-Pain. Load up the \$3 app, sing into your phone's mic, and the program does the rest.

PM

Got a technology problem?

Ask **Seth** about it.

Send your questions to pmdigitalclinic@hearst.com or to Digital Clinic, Popular Mechanics, 300 W. 57th St., New York, NY 10019-5899. While we cannot answer questions individually, problems of general interest will be discussed in the column.



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The New Wildcatters

(CONTINUED FROM PAGE 97)

Though only partially built out, the specs for Mueller, a partnership between the Catellus Development Group and the city of Austin, are already impressive. Mueller includes the world's greenest hospital, more than 75 acres of parkland and 13 miles of bike trails and sidewalks connecting 550 homes—a quarter of which are affordable housing and all of which have been built to Austin Energy's green building standards. The master plan includes native prairie to sequester carbon, a reclaimed water system for irrigation, a town center, a children's museum and housing and employment for 10,000 people.

But McCracken sees an even more ambitious vision playing out here—that of a solar-powered “energy Internet.” He is the driving force behind the Pecan Street Project, a nonprofit dedicated to making Austin a laboratory for smart-grid technology. “In the home of the future, you will be able to look at an app on your phone that tells you what your energy usage is, what it’s costing you and how it impacts your preset electric budget,” McCracken says. “You’ll be able to see what individual appliances, whether the refrigerator or air conditioner, are costing you in real time. And you’ll be able to control that.” Utilities will be able to take advantage of the same software to measure and manage energy flow.

As a demonstration site for the Pecan Street Project (pending federal stimulus funding), Mueller would link 1000 residential meters, 75 commercial meters and plug-in-vehicle-charging stations on a microgrid, testing technologies such as energy storage as well as business models like rooftop solar leasing. “It’s technically challenging, but so is the Internet, where you have millions of computers feeding into servers and distributing it out,” McCracken says. “The big advantage we have is the extent to which this is now a technology strategy. We’re a very entrepreneurial state. And we have some regulatory flexibilities and a business culture that’s been really conducive to the high-tech sector.”

Besides partners like the University of Texas and the Environmental Defense Fund (EDF), the Pecan Street Project has attracted private companies, including Microsoft, Intel and IBM, that will be able to test their own technologies in a real-world setting—without the approval of the Federal Energy Regulatory Commission. “They see smart-grid deployment as something that is going to go into their markets, so they really want to find out how this all works,” John Baker, chief strategy officer for Austin Energy, says.

Austin Energy is municipally owned and vertically integrated—its board is the city council and its customers are its shareholders—so the utility has

our way.” When a major wind turbine manufacturer considered sites in Texas for a factory, Wortham says, the state let towns sell themselves. “It’s like *The Apprentice*,” he says. “It slides a little package across the way.” Pennsylvania’s governor promoted the entire commonwealth as a site and got that factory—which led to others.

Last December, before the 2009 state legislative session began, I had breakfast with McCracken and representative Strama. McCracken was characteristically cerebral but optimistic. Gesturing over a plate of huevos rancheros, he painted a new picture of South Lamar Street, which is the heart of South Austin—“the funky soul of our city.” Instead



“That’s where Texas thinks we’re big dogs. Texans do things differently. We’re independent and sometimes that gets in our way.”

**GREG WORTHAM,
MAYOR OF SWEETWATER**

been able to take the long view on alternative energy: It has led the Pecan Street Project, established the country’s first green building standards, distributed smart meters and pushed auto companies to develop plug-in vehicles. State leadership has not been nearly as progressive. The legislature meets for only 140 days every other year. This year, despite bipartisan support, only one of 50 bills with solar incentives passed before the session ended; the legislature meets again in January 2011.

“I think we’re a little schizophrenic,” James Marston, the director of EDF’s Texas office, says. “We know wind worked and we got some jobs, but we’re not as aggressive as Colorado or New Mexico or even Michigan [on renewable energy], and we’re missing out.”

On that point, Sweetwater’s Wortham agrees. “That’s where Texas thinks we’re big dogs,” he says. “Texans do things differently. We’re independent and sometimes that gets in

of lube shops, used-car dealers and gas stations—businesses serving the existing energy economy—he described the future of South Lamar under a distributed electrical system, one that will open up the economy to green-collar jobs and lots of small, local entrants.

“We can totally screw this up,” Strama said, kicking back in his chair from the heavy wooden table. “The energy industry is going to evolve. It can either go the way of the evolution from radio to television, where the existing broadcasters saw change coming, invested in it, and led the change. Or,” he said, “it can evolve the way we went from TV to the Internet, where those guys didn’t see change coming, and a couple of kids in a garage in California built a company bigger than all of them.”

With clean energy poised to become the biggest economic opportunity since the oil boom, that is what’s at stake for Texas.

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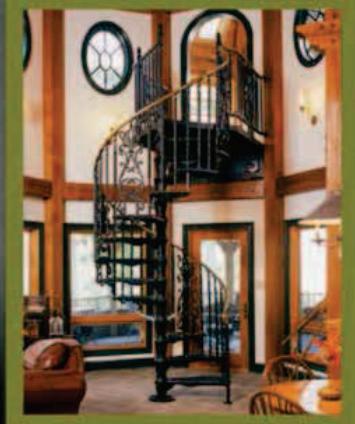
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DARYL SMITH
LOCATION: NEW HAVEN, CONN.
AGE: 48
YEARS ON JOB: 23



Daryl Smith didn't set out to custom-build radiation detectors.

After choosing glass blowing over graduate school, he spent years working for pharmaceutical and chemical companies; becoming a glass blower at Yale University allowed him to use his old-fashioned craft to create state-of-the-art scientific tools. Now he gets all sorts of requests: alterations to standard equipment, designs for prototypes, even glass rods for a detector that went into CERN's Large Hadron Collider in Europe. The machine reveals radiation emitted by charged particles traveling faster than the speed of light—the equivalent of traveling backward in time, according to Einstein's theory of relativity. "I tell people I'm making a time machine," Smith says. —ANDREW MOSEMAN

1. *Didymium Goggles*

Smith's lenses, made from the metallic elements praseodymium and neodymium, filter out wavelengths of visible and UV light—like yellow sodium flare—to help Smith see.

2. Cradle Burner Smith starts with ordinary glass tubes and rods as his raw materials, made from the same borosilicate glass as standard lab instruments. This U-shaped series of torches lets him blast heat evenly from six directions.

3. Lathe This lathe allows Smith to evenly heat or make a clean cut around a tube. The jaws can also hold a piece in place while he melts and attaches another to it.

4. Gas At 4100 F, a natural gas–oxygen flame melts most of the materials Smith uses. But if the final product needs to withstand very high temperatures, he uses tougher pure-quartz glass and switches to a hydrogen–oxygen flame that reaches 5250 F.

5. Carbon Forming Tools Molten glass won't stick to pure carbon, so the tools Smith uses are made of graphite, which heats up so quickly that it matches the temperature of the glass and minimizes thermal shock.

6. Vacuum System This system lets Smith confirm that a finished piece is airtight. He runs a small Tesla coil over the instrument's surface; if there's a leak, the charge will take the path of least resistance and jump to the hole.

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